THE

COLLECTED WORKS

OF

SIR HUMPHRY DAVY, BART.

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SIR HUMPHRY DAVY, BART.

LL.D. F.R.S.

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC.

EDITED BY HIS BROTHER,

JOHN DAVY, M.D. F.R.S.

VOL. VII. 7

DISCOURSES DELIVERED BEFORE THE ROYAL SOCIETY;

AND

AGRICULTURAL LECTURES, PART I.

LONDON:
SMITH, ELDER AND CO. CORNHILL.
1840.

LONDON:
PRINTED BY STEWART AND MURRAY, OLD BAILEY.

DISCOURSES

DELIVERED BEFORE

THE ROYAL SOCIETY:

ELEMENTS

OF

AGRICULTURAL CHEMISTRY,

PART I.

LONDON:
SMITH, ELDER AND CO. CORNHILL.
1840.

Chem 78.1

[Owing to circumstances connected with the interests of copy-right, it has been necessary to give the author's Lectures on Agricultural Chemistry, in two volumes, conjoined with other topics; thus, in the present volume they are preceded by his Discourses delivered before the Royal Society in the capacity of President at the anniversary meetings; by some delineations of character of distinguished men, extracted from his unpublished Lectures on Chemistry; and by a portion of a Journal of a tour in Ireland in 1806; and in the next volume they will be followed by examples of the same Lectures; showing, however imperfectly, his manner of addressing a mixed audience, such as that which always assembled in the theatre of the Royal Institution, and the kind of eloquence, acknowledged by all who ever heard him, by which he succeeded in fixing the attention and exciting an interest in matters of science.

His Discourses delivered before the Royal Society were published at the request of the Council of the Society, and, as has been mentioned in the first volume, shortly after his last election to the office of President, and when labouring under serious illness, the first attack of that malady which ultimately proved fatal. Amongst papers which have come into the editors possession since that volume was written, there is one expressive of the feeling of the Society towards him as President, and specially referring to these Discourses, which it may be right to insert here. It is, verbatim, as follows, written on parchment:—

"At a meeting of the Royal Society, held on Thursday, the 15th of November, 1827, the President stated from the chair, that he was directed

by the Council to submit the following resolution to the Society which was *unanimously* agreed to:

"That the regret of the Fellows of the Royal Society be expressed in the strongest terms to their late excellent President Sir Humphry Davy, Baronet, for the state of health which has unhappily compelled him to relinquish the chair; together with their thanks for the unremitting diligence with which he has at all times endeavoured to promote the interests of science, and the welfare of the Royal Society, and for the learned and eloquent discourses which at each anniversary during his Presidency he concluded the business of the year."]

ERRATA.

line 9, *for* Patrons read Patron.
— 16, *for* elastic gum read gum-elastic.
— 7, *after* saccharine *add* matter.
— *for* salt *read* salts.
for applied *read* supplied.

CONTENTS.

ERRATA.

Page 6, line 9, *for* Patrons *read* Patron.
275, — 16, *for* elastic gum *read* gum-elastic.
293, — 7, *after* saccharine *add* matter.
341, — 31, *for* salt *read* salts.
342, — 15, *for* applied *read* supplied.

(Continued in Vol. VIII.)

DIRECTIONS FOR THE PLATES.

SIX DISCOURSES

DELIVERED BEFORE

THE ROYAL SOCIETY

AT THEIR

ANNIVERSARY MEETINGS,

ON THE

AWARD OF THE ROYAL AND COPLEY MEDALS;

PRECEDED BY

AN ADDRESS TO THE SOCIETY,

ON THE

PROGRESS AND PROSPECTS OF SCIENCE.

ADVERTISEMENT.

I HAVE published these Discourses in compliance with the wishes of the Council of the Royal Society. I hope they will be read by the public in the same spirit in which they were heard by the Fellows. They were intended to communicate general views on the particular subjects of science to which they relate, and not minute information. They must not be considered as finished dissertations;—their principal object was to endeavour to keep alive the spirit of philosophical inquiry and the love of scientific glory.

Park-street, Jan. 3, 1827.

ADDRESS OF THE PRESIDENT ON TAKING THE CHAIR OF THE ROYAL SOCIETY, FOR THE FIRST TIME; DECEMBER 7TH, 1820.—ON THE PRESENT STATE OF THAT BODY, AND ON THE PROGRESS AND PROSPECTS OF SCIENCE.

GENTLEMEN,

I HAVE, on a former occasion,* returned you my thanks for the distinguished honour you have done me in electing me your President. I have stated to you my entire devotion to your interests, and to the cause of science. I do not mean to indulge in any further expression of my feelings on this occasion, except to say that they are deep, and will be permanent.

But I think it my duty, before I enter upon the details of common business, to devote a few words to the present state of the Royal Society, its relations to other scientific bodies, and the prospects and hopes of science.

In the early periods of our establishment, when apparatus was procured with difficulty, when the greatest philosophers were obliged to labour with their own hands to frame their instruments, it was found expedient to keep in the rooms of the Society a collection of all such machines as were likely to be useful in the progress of experimental knowledge: and curators and operators were employed, by whom many capital experiments were made under the eyes of the Society. But since the improvement of the mechanical and chemical arts have afforded great facilities as to the means of

* At the anniversary dinner, November 30.

carrying on experimental research, the Transactions of the Fellows, recorded by the Society, have, with some few exceptions, been performed in their own laboratories, and at their own expense. It is, however, possible that experiments of great importance, requiring funds, which few individuals can command, may be suggested; and it is to be hoped that, on such occasions, the proposers will not fail to recur to the Society. Government, by the command of our august patrons, has always been found ready to assist us, when our inquiries have been connected with objects of national interest; and, on inferior occasions, the aid required might be afforded by an union of the Fellows, many of whom, from their situation in public establishments for teaching and diffusing natural knowledge, have opportunities of procuring the use of grand and expensive apparatus.

When the Royal Society was instituted, it stood alone in Britain; and the associations of learned men that were formed soon after, in different parts of the empire, for pursuing natural science, were either dependent or affiliated societies. But, in these latter times, the field of knowledge has become so extensive, and its objects so various, that separate and independent bodies have arisen for registering observations and collecting facts, each in a different department. It would be impossible that our records, as they are now published at our own expense, should contain histories of the multifarious phenomena of all the kingdoms of nature, of all the observations made in zoology, botany, mineralogy, geology, and practical astronomy. It is satisfactory, therefore, to know that institutions exist for preserving and publishing such histories in detail.

I trust that, with these new societies, we shall always

preserve the most amicable relations, and that we shall mutually assist each other; and that they, recollecting our grand object, which is to establish principles on inductive reasoning and experiments, and to make useful applications in science, will, should any discoveries be made by their members respecting general laws, or important facts observed, which seem to lead to purposes of direct utility, do us the honour to communicate them to us. They will have no dishonourable place in being published in those records, which remain monuments of all the country has possessed of profound in experimental research, or ingenious in discovery, or sublime in speculative science, from the time of Hooke and Newton, to that of Maskelyne and Cavendish.

I am sure there is no desire in this body to exert anything like patriarchal authority, in relation to these institutions; or, indeed, if there were such a desire, it could not be gratified. But I trust there may exist in the new societies, that feeling of respect and affection for the Royal Society, which is due to the eldest brother, to the first-born of the same family; and that we shall co-operate, in perfect harmony, for one great object, which, from its nature, ought to be a bond of union and of peace, not merely amongst the philosophers of the same country, but even amongst those of different nations.

When, by the unrivalled power of one great genius, and the industry and talent of his illustrious disciples, the laws of the motions of the great masses of matter composing the universe were discovered, and most of the physical phenomena connected with them solved, it appeared as if the field of scientific research were exhausted, as if the rich crops taken from the soil had rendered it steril, and that little was left for the inge-

nuity and labour of future inquirers; time, however, has proved how unfounded was this opinion, and how nearly approaching to infinite, are the objects of natural philosophy. Scarcely has any period of thirty years passed without offering a train of important discoveries, and every new truth or new fact has led to new researches; becoming, as it were, a centre of light, from which rays have proceeded in different directions, showing to us unexpected objects; so that this kind of knowledge is as inexhaustible, as the resources of the human mind; and philosophers, like the early cultivators in a great new continent, by every acquisition they make, discover new and extensive uncultivated spots beyond. As a chart of what is known in lately-discovered regions is essential in guiding the traveller to new researches, so, in natural knowledge, notices of the limits or boundary lines of different new departments of science, and of the aspects and characters of novel objects may be useful to scientific investigators; I shall, therefore, offer a few hints respecting those different departments of inquiry which appear most capable of improvement.

In pure mathematics: though their nature, as a work of intellectual combination, framed by the highest efforts of human intelligence, renders them incapable of receiving aids from observations of external phenomena, or the invention of new instruments, yet they are at this moment abundant in the promise of new applications; and many of the departments of philosophical inquiry, which appeared formerly to bear no relation to quantity, weight, figure, or number, as I shall more particularly mention hereafter, are now brought under the dominion of that sublime science, which is, as it were, the animating principle of all the other sciences.

When the boundary of the solar system was enlarged

by the discovery of the Georgium Sidus, and the remote parts of space accurately examined by more powerful instruments than had ever before been constructed, there seemed little probability that new bodies should be discovered nearer to our earth than Jupiter; yet this supposition, like most others in which our limited conceptions are applied to nature, has been found erroneous. The discoveries of Piazzi, and those astronomers who have followed him, by proving the existence of Ceres, Pallas, Vesta, and Juno—bodies smaller than satellites, but in their motions similar to primary planets—have opened to us new views of the arrangement of the solar system. Astronomy is the most ancient, and the nearest approaching to perfection, of the sciences; yet, relating to the immensity of the universe, how unbounded are the objects of inquiry it presents! And, amongst them, how many grand and abstruse subjects of investigation! Such, for instance, as the nature of the systems of the fixed stars and their changes, the relations of cometary bodies to the sun, and the motions of those meteors which, in passing through our atmosphere, throw down showers of stones; for it cannot be doubted that they belong to the heavens, and that they are not fortuitous or atmospheric formations; and, in a system which is all harmony, they must be governed by fixed laws, and intended for definite purposes.

The grand question of universal gravitation, and its connexion with the figure of the earth, has been long solved; but the mechanical refinements of one of our Fellows, have afforded means of estimating, with more perfect exactness, the force of gravity: and that pendulum, which is so well fitted as a standard of measure, may be admirably applied in acquainting us with the physical constitution of the surface of the earth. I trust

we shall have some interesting new experiments on the subject. Our brethren of the Royal Academy of Sciences of Paris, who have laboured with so much zeal and activity towards the measurement of a great arc of the meridian in France and Spain, are, I know, extremely desirous their measures may be connected with those carried on by the command of the Board of Ordnance in Britain,—that the work may be completed by the philosophers of both countries. Should this be done, there will be established, on the highest authority, an admeasurement of nearly 20 degrees, or $\frac{1}{18}$th of the whole circumference of the earth, from the Shetland Islands to Formentera, which will be a great record for posterity, and an honour for our own times.

I cannot pass over the subject of the figure of the earth without referring to the late voyage to the Arctic Regions, which has shown that there is an accessible sea to the west of Baffin's Bay, presenting hopes of other discoveries, and which, though unsuccessful in its immediate objects, has terminated, nevertheless, in a way equally honourable to those by whom the expedition was planned, and to the brave, enterprising, and scientific navigators by whom it was executed. Such expeditions are worthy of the great maritime nation of the world, showing that her resources are not merely employed for gaining power or empire, but likewise for what men of science must consider as nobler purposes, the attempting discoveries which have the common benefit of mankind for their object, and the extension of the boundaries of science.

In the theory of light and vision, the researches of Huyghens, Newton, and Wollaston, have been followed by those of Malus; and the phenomena of polarization, which we owe to the genius of that excellent and much

to be lamented philosopher, are constantly leading to new discoveries; and, notwithstanding the important labours of Arago, Biot, Brewster, and Herschel, the inquiry is not yet exhausted; and it is extremely probable, that these beautiful results will lead to a more profound knowledge than has hitherto been obtained, concerning the intimate constitution of bodies, and establish a near connexion between mechanical and chemical philosophy.

The subject of heat, so nearly allied to that of light, has lately afforded a rich harvest of discovery; yet it is fertile in unexplored phenomena. The question of the materiality of heat will probably be solved at the same time as that of the undulatory hypothesis of light, if, indeed, the human mind should ever be capable of understanding the causes of these mysterious phenomena. The applications of the doctrine of heat to the atomic or corpuscular philosophy of chemistry, abound in new views, and probably, at no very distant period, these views will assume a precise mathematical form. There are many remarkable circumstances which seem to point to some general law on the subject:—first, the apparent equable motion of radiant matter, as light and heat, through space; second, the equable expansion of all elastic fluids, by equal increments of temperature; third, the contraction or expansion of gases, by chemical changes, in some direct ratio to their original volume, for instance $\frac{1}{2}$ or $\frac{1}{3}$; fourth, the circumstance that the elementary particles of all bodies, appear to possess the same quantity of heat.

In electricity, the wonderful instrument of Volta, has done more for the obscure parts of physics and chemistry, than the microscope ever effected for natural history, or even the telescope for astronomy. After

presenting to us the most extraordinary and unexpected results in chemical analysis, it is now throwing a new light upon magnetism,

Suppeditatque novo confestim lumine lumen.

But upon this question I shall enter no further, as it has been discussed, in the discourse given on the award of the Copleian medal to M. Œrsted, by my predecessor in office,* with all his peculiar sagacity and happy talent of illustration.

To point out all the objects worthy of inquiry in chemistry, would occupy the time appropriated to many sittings of the Society. I cannot, however, avoid mentioning, amongst important desiderata, the knowledge of the nature of the combinations of that principle existing in fluor, or in Derbyshire spar, and which has not yet been obtained pure; the relations of that extraordinary fact, the metallization of ammonia, and the connexion between mechanical and chemical phenomena, in the action of voltaic electricity. I must congratulate the Society on the rapid advances made in the theory of definite proportions, since it was advanced in a distinct form, by the ingenuity of Mr. Dalton. I congratulate the Society on its progress, and on the promise it affords of solving the recondite changes, owing to motions of the particles of matter by laws depending upon their weight, number, and figure, and which will be probably found as simple in their origin, and as harmonious in their relations, as those which direct the motions of the heavenly bodies, and produce the beauty and order of the celestial systems.

The crystallizations, or regular forms of inorganic matter, are intimately connected with definite propor-

* [Dr. Wollaston.]

tions, and depend upon the nature of the combinations of the elementary particles; and both the laws of electrical polarity, and the polarization of light, seem related to these phenomena. As to the origin of the primary arrangement of the crystalline matter of the globe, various hypotheses have been applied, and the question is still agitated, and is perhaps above the present state of our knowledge; but there are two principal facts which present analogies on the subject, one, that the form of the earth is that which would result, supposing it to have been originally fluid; and the other, that in lavas, masses decidedly of igneous origin, crystalline substances, similar to those belonging to the primary rocks, are found in abundance.

In following the sensible phenomena of nature, from the motions of the great masses of the heavenly bodies which first impress the senses and affect the imagination, to the changes individually imperceptible, which produce the results of crystallization, there is a regular gradation, and a series conformable to analogy; and where crystallization ends, another series, that of animated nature, begins, governed by a distinct set of laws, but obedient to a principle, the properties of which, independent of matter, can never be submitted to human observation. The functions and operations of organized beings, however, offer an infinite variety of beautiful and important objects of investigation. For instance, in those refined chemical processes, by which the death and decay of one species afford nourishment to another and higher order, by which the water and inert matter of the soil and the atmosphere are converted into delicately-organized structures, filled with life and beauty. In vegetable physiology, how many phenomena still remain for investigation! the motion

of the sap, the functions of the leaves, for instance, and the nature of the organs of assimilation. In animal physiology, the subjects are still more varied, more obscure, and of a higher character. May we not hope those philosophers of the schools of Grew and Hunter, who have already done so much for us, will not cease their efforts for the improvement of these branches of science, which are not merely important in their philosophical relations, but of great utility, the one to agriculture, the other to medicine?

Gentlemen, to conclude, I trust in all our researches we shall be guided by that spirit of philosophy, awakened by our great masters, Bacon and Newton; that sober and cautious method of inductive reasoning which is the germ of truth and of permanency in all the sciences. I trust that those amongst us who are so fortunate as to kindle the light of new discoveries, will use them, not for the purpose of dazzling the organs of our intellectual vision, but rather to enlighten us, by showing objects in their true forms and colours; that our philosophers will attach no importance to hypotheses, except as leading to the research after facts so as to be able to discard or adopt them at pleasure, treating them rather as parts of the scaffolding of the building of science, than as belonging either to its foundations, materials, or ornaments; that they will look, where it be possible, to practical applications in science, not, however, forgetting the dignity of their pursuit, the noblest end of which is, to exalt the powers of the human mind, and to increase the sphere of intellectual enjoyment, by enlarging our views of nature, and of the power, wisdom, and goodness of the Author of nature.

Gentlemen, the Society has a right to expect from those amongst its Fellows, gifted with adequate talents,

who have not yet laboured for science, some proofs of their zeal in promoting its progress; and it will always consider the success of those who have already been contributors to our volumes, as a pledge of future labours.

For myself, I can only say, that I shall be most happy to give in any way assistance, either by advice or experiments, in promoting the progress of discovery. And though your good opinion has, as it were, honoured me with a rank similar to that of general, I shall be always happy to act as a private soldier in the ranks of science.

Let us then labour together, and steadily endeavour to gain what are perhaps the noblest objects of ambition —acquisitions which may be useful to our fellow-creatures. Let it not be said, that, at a period when our empire was at its highest pitch of greatness, the sciences began to decline; let us rather hope that posterity will find, in the Philosophical Transactions of our days, proofs that we were not unworthy of the times in which we lived.

DISCOURSE OF THE PRESIDENT,

NOVEMBER 30TH, 1821,

In announcing the Award of two Medals on Sir GODFREY COPLEY'S Donation. One to J. W. F. HERSCHEL, Esq., F.R.S., for his various Papers on Mathematical and Physico-Mathematical Subjects, published in the Philosophical Transactions. And the other to Captain EDWARD SABINE, R.A., for his Papers containing an Account of his various Experiments and Observations, made during the Voyage and Expedition in the Arctic Regions.

GENTLEMEN,

THE progress of discovery, even when belonging to past times or to distant countries, is always an agreeable subject of contemplation to philosophical men; but the pleasure derived from it is much higher when it arises from the exertions of the talents of our own countrymen, when it originates in our own body, and when there is the power, not only of acknowledging and rejoicing at it, but likewise of distinguishing the persons to whom it is owing by a permanent mark of respect. You will therefore, I am sure, Gentlemen, have as much satisfaction in hearing, as I have in stating, the decision of the council of the Royal Society, in the award of two of your Copley medals, — one of this year, and one not disposed of on a former occasion, — to two of our worthy Fellows, whose papers have been published in the *Philosophical Transactions*, and whose merits have been for some time known to you, — John Frederick William Herschel, Esquire, and Captain Edward Sabine, of the Royal Artillery. I shall ask your attention for a short time, Gentlemen, whilst

I state the grounds of the decision of your council, and I shall begin with the labours of Mr. Herschel.

There is certainly no branch of science so calculated to awaken our admiration as the sublime or transcendental geometry, not only as showing the wonderful powers and resources of the human mind, but likewise demonstrating the wisdom and beauty of the laws of the system of the universe. It is, perhaps, the highest triumph of human intelligence, that, proceeding from the consideration of mere unities or points, lines, or surfaces, it should, by gradual generalizations, substitutions, and abstractions, be able to arrive, not only at the knowledge of all possible conditions of number and quantity, but likewise of time and motion; and by employing its own pure intellectual creations, to anticipate the results of observation and experiment, and determine the movements, not only of the bodies which form permanent parts of our system, but likewise of those which seem only occasionally to visit it, and which belong, as it were, to the immensity of space.

Whether the importance of the subject be considered, or the glory that has been derived by the society from the labours of those amongst its members who have cultivated the higher branches of the mathematics, it must be very gratifying to you to hear that Mr. Herschel, after gaining, at a very early period of life, academical honours of the highest kind in that university where the exact sciences are most profoundly studied, has successfully continued his pursuit of this kind of knowledge: and not contented with understanding and illustrating the most elaborate works of his predecessors and contemporaries, has made additions to them, and that even in the most abstruse and difficult branches of analysis.

Four papers of Mr. Herschel, on pure mathematical subjects, are to be found in your *Transactions*. The first, on a remarkable application of Cotes's theorem. The second, on the consideration of various parts of analysis, in which he has examined one of the most sublime points of the doctrine of fluxions, the calculus of generating functions, and makes a new application of them to the case of logarithmic transcendents, and derives from them the summation of one of the most important series which has ever received discussion. The third paper is on the development of exponential functions, together with several new theorems relating to finite differences. The fourth paper is on circulating functions, and the integration of a class of finite differences into which they enter as co-efficients.

I cannot attempt an analysis of these papers; that their merits may be understood, they must be deeply studied; and, by the best mathematicians, they are regarded as ingenious and profound.

The author, in treating of algebraical or fluxional instruments, as they may be called, of the relations of variable quantities or functions which may be supposed capable of indefinite diminution or increase, has indulged in no vague metaphysical abstractions. He has shown a great love of simplicity in his processes, appearing rather desirous of being intelligible and useful, than anxious to display the variety and extent of his acquisitions. In all these papers Mr. Herschel has proved himself intimately acquainted with the works of the great masters of analysis, and has exhibited equal powers of seizing particular applications of methods already known, and of developing new and general views; thus demonstrating himself the worthy associate of a Brinkley, a Woodhouse, an Ivory, and a Young,

who have, in late times, travelled, with so much zeal and success, towards mathematical discoveries, in these noble paths of investigation opened by the unrivalled genius of Newton, and too long deserted by our countrymen, and occupied, almost exclusively, by illustrious foreigners.

But Mr. Herschel has not limited himself to the invention or development of formulæ, to what may be called the construction of the instruments of the science of quantity, he has made important applications of them, which is perhaps the highest claim that can be made to the approbation of this Society; for though, as a mere exercise, the higher mathematics strengthen the reasoning faculties, and afford intellectual pleasure, yet it is by enabling us to solve the physical phenomena of the universe, and modify the properties of matter, that they have their grandest end and use. In these respects, they are really power; and they may be compared to that power which we witness in the vapour of water, which, passing into the free atmosphere, exhibits only a pleasing spectacle; but which applied in the steam-engine, becomes the moving principle of the most useful and extensive machinery, and the source of the most important arts of life.

There are two papers of Mr. Herschel's, in the last volume of the *Transactions*, on physico-mathematical subjects, and both of them connected with optical phenomena. All the Fellows must be acquainted with the beautiful discoveries of Malus, of that peculiar modification given to rays or particles of light, by their passage through certain transparent bodies, or by their reflection from certain surfaces, which has been called polarization; and the ingenious and elaborate researches of Biot, Arago, and Brewster, in consequence of the

discovery, have been illustrated from this chair by your venerable and illustrious deceased President. But, notwithstanding the talents and industry of these distinguished philosophers, Mr. Herschel has been able to add to the subject some novel investigations; and, in reasoning upon the tints developed by polarized light, has reduced the explanation of the phenomena to one general fact—namely, that the axes of double refraction differ in their position in the same crystal, for the different-coloured rays of the spectrum, and that this element must enter into all rigorous formulæ of double refraction; and, consequently, that the idea of the colours of thin plates being correspondent with the tints developed by polarized light, is not conformable to the facts.

Though it appears that some similar observations were made by one of the philosophers just mentioned, without the knowledge of what Mr. Herschel had done, yet the latter has unquestionably the priority: and it is agreeable to find a harmonious coincidence between two accurate reasoners and acute observers.

In this paper Mr. Herschel has extended or modified the discoveries of others: the second is more original, and on a subject highly important in practical objects.

With the view of enabling artists to substitute, in working their glasses, certain mathematical rules for empirical methods, Mr. Herschel has presented, under a general and uniform analysis, the whole theory of the aberration of spherical surfaces, and has furnished simple tabular rules, by which the workmen may adapt their tools to the object required, in forming glasses for the telescope; thus adding to the immense obligations owing to the name of Herschel, in every thing connected

with the progress of modern astronomy, and the knowledge of celestial phenomena.

Convinced, Gentlemen, that you approve of the decision of your Council, I shall present this medal, engraved with his name and the date of the year, to Mr. Herschel.

Mr. Herschel,

Receive this medal, Sir, as a mark of our respect and of our admiration of those talents which you have applied with so much zeal and success, and preserve it as a pledge of future exertions in the cause of science, and of the Royal Society; and, believe me, you can communicate your labours to no public body by whom they will be better received, or through whose records they will be better known to the philosophical world. You are in the prime of life, in the beginning of your career, and you have powers and acquirements capable of illustrating and extending every branch of physical inquiry; and, in the field of science, how many are the spots not yet cultivated! Where the laws of sensible become connected with those of insensible motions, the mechanical with the chemical phenomena, how little is known! In electricity, magnetism, in the relations of crystallized forms to the weights of the elements of bodies, what a number of curious and important objects of research! And they are objects which you are peculiarly qualified to pursue and illustrate.

May you continue to devote yourself to philosophical pursuits, and to exalt your reputation, already so high,

"Virtutem extendere factis."

And these pursuits you will find not only glorious but dignified, useful, and gratifying in every period of life:

this, indeed, you must know best in the example of your illustrious father, who, full of years and of honours, must view your exertions with infinite pleasure; and who, in the hopes that his own imperishable name will be permanently connected with yours in the annals of philosophy, must look forward to a double immortality.

I shall now speak of the researches of Captain Sabine. You will, Gentlemen, I am sure, anticipate the grounds of the decision of your Council, in awarding to him the other medal.

The expeditions to the Arctic Regions, which have been planned with so much liberality of view by the Admiralty, and which are carrying on with so much skill, perseverance, and courage by the brave officers and seamen concerned in them, have awakened so strong an interest in the public mind, and are so well known in the printed details, that it is almost unnecessary to point out the particular merits of the most distinguished amongst those bold and enterprising persons who have thus devoted themselves to the cause of science and their country. Yet, Captain Sabine having been appointed, in consequence of the recommendation of the Council of the Royal Society, astronomer and philosophical observer to the two first of the expeditions, and having more than answered their recommendation, they have thought it right to express their sense of his high merits, by the vote I am now announcing.

Captain Sabine had been for some time known as an active officer, and by his labours in these expeditions, he has proved himself worthy the name of an accurate philosophical observer: he has shown great industry and perseverance in making his experiments, under circumstances when they were peculiarly difficult, and has

accumulated an immense number of observations in astronomy and meteorology, and on the phenomena of magnetism and gravitation.

Active courage, Gentlemen, is a quality so inherent in every Briton, and so nobly displayed in our naval and military triumphs, that it is scarcely necessary to praise it; but, there is a fortitude and a patience in enduring hardships, and in bearing privations, which may be considered as rarer qualities, and which demand our highest commendation. The place, as you know, where Captain Sabine conducted his principal experiments was on the ice of the Polar Sea, where the vessel was for several months frozen up. During a considerable portion of the time, he was in darkness, or only guided by a very doubtful twilight; and such was the intensity of the cold, that exposure, even in the warmest clothing, to the atmosphere for any time, was always painful, and sometimes dangerous. It was impossible to touch the metallic instruments with the naked hand, without being frost-bitten; and such was the temperature of this inclement spot, probably as cold as any belonging to the northern hemisphere, that the artificial horizon of mercury became frozen during an observation; yet Captain Sabine's experiments seem to have been conducted with as much care and precision, as if he had been possessed of the conveniences and luxuries of a royal observatory, and the advantages and repose of the happiest climate and situation.

Three of his papers have been published in your *Transactions*: the two first contain observations relating to magnetic phenomena, such as, the influence of the iron in the ship, upon the correctness of results obtained by the compass, and the intensity and variation of the magnetic force in approaching the

magnetic pole, which last are given in a series of tables. The other paper is more important, containing an account of experiments on the vibrations of the pendulum, in different latitudes.

On the subject of this paper, I shall enter into a few details. The invention of the pendulum, by Galilæo Galilæi, is placed beyond all doubt; and that this illustrious philosopher endeavoured to apply it as a measure of time, and that his son, Vincenzo Galilæi constructed the first pendulum clock at Venice, 1649, is proved, both by manuscript documents that I have seen at Florence, and by the printed testimonies of the Academia del Cimento; but the great principle of the instrument, in its application to clock-work, it is well known, is owing to the illustrious Huyghens, who discovered that the vibrations were isochronous, when performed in cycloidal arcs.

It is not certain by whom the pendulum was first proposed as an universal standard of measure, but it is hardly likely that such an application of it should have escaped the sagacity of the Dutch philosopher; yet, as early as 1661, Lord Brouncker, after mathematically demonstrating the properties of the pendulum, by a very elaborate analysis, brought in a paper to the Royal Society on a common measure, and Sir William Petty, at the same meeting, proposed to make experiments, for this purpose, on the vibrations of the pendulum, and Sir Christopher, then Doctor, Wren, was desired to think of some other common measure, and he proposed, on his return from Oxford, a certain part of the length of a degree upon the earth. Various experiments, likewise, seem to have been made by different members of the Royal Society, between 1661 and 1664, on the times of the vibrations of pendulums of different lengths,

as standards of measure; and Huyghens did not propose the pendulum vibrating seconds, as an universal standard, till the end of this year, November, 1664; and that, in a letter to the Royal Society, but the proposition is given in a very precise and beautiful form.

When the calculations of Newton and Huyghens, and the experiments of Richer, had proved that the vibrations of the same pendulum were not performed in the same time in different latitudes, M. de la Condamine proposed, and endeavoured to establish, the length of the pendulum vibrating seconds at the equator, as a common standard. But in no part of Europe was this standard adopted; and the French metre, as you well know, is founded upon the measure by triangulation, made by some distinguished members of the Institute, of a small arc of the meridian.

It is to the scientific zeal and enlightened views of our worthy treasurer, Mr. Gilbert, that the elaborate investigation of the properties of a pendulum, as an universal standard of measure, is owing. By making it a question of national importance in Parliament, he directed all the scientific talents and resources of the country to the object; and the invariable pendulum, contrived with such a happy spirit of invention, and examined with such unceasing activity and minute accuracy by Captain Kater, was the fortunate result.

The experiments made with this beautiful instrument, by the inventor, are well known to you, having been published at full length in your *Transactions*. Captain Kater's results proved that it was a most delicate measure of gravity, not only for the whole earth, but likewise as even marking the density of particular parts of the surface; and his conclusions rendered it very desirable, that the length of the pendulum, or,

what is tantamount, the number of its vibrations, should be determined as extensively as possible, from the Polar to the Equatorial Regions.

A happy opportunity occurred, with respect to the Arctic Pole, in the two late expeditions; and Captain Sabine, being provided with the necessary means, applied them with all possible accuracy and industry, as the details of his paper prove; and in north latitude of nearly $74\frac{1}{2}$ degrees, the extreme point of his observations, he has shown the length of the pendulum vibrating seconds, to be 39·207 inches, and the mean of his experiments gives the compression of the earth, at the Pole, as $\frac{1}{313}$.

Captain Sabine did not accompany the third expedition, because he conceived that he had effected all that he was capable of performing with the pendulum in north latitudes, which was the great object of his researches in the two former voyages; and his scientific ardour made him resolve to endeavour to complete his investigation even to the Line; and it is in consequence of his carrying this resolution into effect, that he is not now present to witness the strong interest you have taken in his pursuits. Having braved the long night, and almost perpetual winter of the Polar Regions, he is gone, with the same laudable object, to expose himself to the burning sun and constant summer of the Equator.

Should Providence bestow on him health and a successful voyage, I have no doubt he will return to us with a valuable collection of facts and observations. He has carried with him instruments of various kinds for making researches,—as to the temperature and currents of the ocean,—the effects of heat and light,—the state of the atmosphere,—and other objects connected with the natural history of the globe. And his researches on the

pendulum, combined with those Captain Kater has made in our own island, and others carrying on at the observatory established at the Cape of Good Hope, and by Sir Thomas Brisbane in New South Wales, will, I have no doubt, furnish a mass of information, from which the figure of the earth may be deduced with much more accuracy, than from any preceding experiments or deductions. And as the Royal Society, through its most illustrious member, had the honour of publishing to Europe, more than a century ago, the grand theoretical principles of this discovery, may we not hope that its present Fellows will give it all the practical elucidations of which it is susceptible?

Captain Sabine not being present, Gentlemen, for the reasons I have stated, I shall deliver the medal to his friend and brother.

MR. SABINE,

In informing Captain Sabine of what has taken place this day, you will, I trust, state to him our deep sense of his merits. His knowledge of this expression of our opinion may, perhaps, animate him during the difficult enterprise he has undertaken; for he has already shown how highly he values the praise of the Royal Society, which, with the good opinion of his countrymen, has been hitherto the only reward of his labours. Assure him how strongly we feel his disinterestedness and genuine love of science, and that our constant wishes are expressed for his safe return, and for the successful accomplishment of all the objects of his voyage, which will ensure, even to him, additional claims upon the gratitude of all lovers of science.

DISCOURSE OF THE PRESIDENT,

ANNIVERSARY, NOV. 30TH, 1822,

On the Characters of some Deceased Fellows; Sir HENRY C. ENGLEFIELD, Bart., Sir WILLIAM HERSCHEL, DR. MARCET, the Rev. SAMUEL VINCE, Dr. PARRY, Dr. CARMICHAEL SMITH, MM. HAUY, DELAMBRE, and BERTHOLLET.—And on the Award of the Medal on Sir GODFREY COPLEY'S Donation, to the Rev. Professor BUCKLAND, for his Paper on the Bones of Hyænas, and other Animals found in a Cave at Kirkdale, in Yorkshire.—With General Views on the Progress and Prospects of Geology.

IN perusing this list (of deaths), Gentlemen, some names have arrested my attention, with respect to which, I consider it as a duty to say a few words. I cannot enter upon a studied eulogy of the illustrious dead;* but I am sure you will not consider a short tribute of

* [The Author's brief eulogies of the illustrious dead in these Discourses were given with the warmth of love and gratitude for scientific worth, without cavil and without disparagement; they display the nobler qualities and higher merits of the individuals, without exposing to the world's scorn their infirmities. This I mention, reflecting with regret, on a contrary procedure of late, relating to men of the loftiest attainments, including even Newton (vide Quarterly Review, No. CIX.), nowise for the interest and glory of science; and which, even if unfounded, will give a handle to the low and worldly minded to scoff at the influence or want of influence of science on the moral mind, and to call in question the noble maxim "that wisdom is justified of her children." Let us not forget the curse of Noah on his youngest son, and his blessing on the elder sons, who with affectionate respect approached him with inverted faces not to see the nakedness they came to cover; an incident deserving of a place, in its allegorical bearing in the *sapientia veterum*, and which, it may well be imagined, Bacon would have applied, in a masterly manner, to the younger sons of science.]

respect to their memory, such as naturally arises out of this occasion, improper or out of place; and which, however unequal it may be to their merits, will, I trust, be in unison with the feelings of the Society.

Sir Henry Englefield, the first person whom I shall mention, was known to you as an accomplished gentleman, gifted with a great variety of knowledge, which he was always ready to communicate. He had followed astronomy much as an amusement, and sometimes as a study; and his early work on comets displays considerable research, and a minute acquaintance with his subject. Though his scientific acquisitions were very general, they were, nevertheless, accurate; and he has produced good papers on several different subjects of experimental research. He was a clear writer, and a learned antiquarian, a liberal collector, and a judge of works of art. In conversation he was ready and fluent, amiable and discursive; and he will long be regretted as an entertaining companion, a warm and excellent friend, a truly honest man, and an ornament to the class of society in which he moved.

On the labours and discoveries of Sir William Herschel, it is unnecessary to dwell; they have so much contributed to the progress of modern astronomy, that his name will probably live as long as the inhabitants of this earth are permitted to view the solar system, or to understand the laws of its motions. The world of science—the civilized world, are alike indebted to him who enlarges the boundaries of human knowledge, who increases the scope of intellectual enjoyment, and exhibits the human mind in possession of new and unknown powers, by which it gains, as it were, new

dominions in space; acquisitions which are imperishable; not like the boundaries of terrestrial states and kingdoms, or even the great monuments of art, which however extensive or splendid, must decay; but secured by the grandest forms and objects of nature, and registered amongst her laws.

The acuteness and accuracy of Sir William Herschel, as an astronomical observer, are demonstrated by his discovery of a new planetary system, and of a number of satellites before unknown. His genius for speculation, and his powers of inductive reasoning, are illustrated by his views of the stars and nebulæ, composing what we know of the system of the universe; and his talents for physical research are shown by his important discovery of invisible rays in the solar spectrum.

The moral qualities of this celebrated man are so well known, that I shall barely touch upon them. Raised entirely by his own merits, and by the powers of his own intellect, to the station he occupied in the world of science, honoured by the patronage and kindness of a most beneficent sovereign, he was spoiled neither by glory nor by fortune, and always retained the native simplicity of his mind. In all his domestic and social relations, he was most amiable. As his life had been useful and honourable, so was his death happy: and he had little left to wish for, except that expansion of intellect which can only belong to the mind in a higher state of existence. Every year of his life was distinguished by some acquisition or blessing; and when age no longer permitted him to make discoveries he saw his son taking his place, and distinguishing himself in the same career.

If the scientific world in general have cause to regret

the loss of Sir William Herschel, and to reverence his memory, the Royal Society, in particular, has a deeper sense of sorrow, and a higher motive for veneration. All his important papers were published in your *Transactions;* and no name in modern times has more contributed to your glory.

Sir William Herschel died at the advanced age of eighty-three; Sir Henry Englefield was seventy; but Doctor Marcet, another of your worthy deceased Fellows, had not much passed fifty years; and his death was most unexpected and deeply to be lamented. He was but a short time before apparently in excellent health and spirits, and active in body and mind. Circumstances of a happy kind likewise enabled him to devote himself entirely to science; and his different papers, published in the *Transactions*, on chemical subjects, show how capable he was of sound reasoning, accurate experiments, and ingenious views, in this department of science; and, I doubt not, had his life been spared, it would have been devoted to laudable scientific objects. A more amiable man than Dr. Marcet, I believe, never lived. There was a simple dignity in his character which commanded respect; and a warmth of manner, arising from a warmth of heart, which ensured affection. But why should I dwell upon moral and social qualities, which all those who knew him must feel, and which I can never describe with sufficient truth to give an idea of, to those who did not know him?

The Rev. Samuel Vince, Plumian Professor of Astronomy and Experimental Philosophy, in the University of Cambridge, was, like Sir William Herschel, a man who rose to distinction entirely by the exertion of his

own talents. He was well known to you as a profound mathematician, and a clear elementary writer. It is enough to say of him, that he was distinguished in the great mathematical school of this country, and that we are now profiting by the labours and profound acquisitions of his scholars.

I shall mention Dr. Parry only as an enlightened and ingenious physician, and an amiable and accomplished man; and Dr. Carmichael Smith, as having received a parliamentary reward for the application of nitrous acid vapour in destroying contagious matter.

On our foreign list, the first name that occurs is the Abbé Hauy, who was known as a good natural philosopher, and whose reputation will pass down to posterity on account of his work on crystallography, in which he has endeavoured to make the crystalline form of mineral bodies, the important character of their classification; and who, in his application of this principle, assisted by chemistry, either produced or prepared the way for some remarkable discoveries.

The next is M. Delambre, Secretary to the Royal Academy of Sciences at Paris; an excellent astronomer, whose work on the History of Astronomy is a model of this kind of composition; he was distinguished by many accurate labours in his favourite science: but his greatest experimental work was that which he made in conjunction with Mechain, the measurement of an arc of the meridian in France. He was a good classical scholar, an elegant and impartial writer; and his Discourses to the Institute, on the annual progress of

science, are marked by good taste, candour, a love of justice, and a truly philosophical spirit.

Berthollet might be considered the patriarch of modern chemistry—the friend and companion of Lavoisier, and Guyton de Morveau. He had contributed much to the establishment of that view of the combinations of oxygen, which has been called the anti-phlogistic system; and took a part in framing the new nomenclature. His principal discovery was that of the composition of ammonia, but he was the author of many excellent papers on chemical subjects; and the most celebrated French chemists now alive were his pupils. He was an excellent logician and a good experimenter; and remarkable for a high degree of candour, renouncing his opinions with the greatest readiness, whenever the progress of science was opposed to them; and this even in old age. He was amiable and unaffected, and the liberal patron of rising genius wherever it appeared; and made a point, even in the bosom of the Academy of Sciences, of doing justice to foreigners.

COPLEY MEDAL.

The duty I have now to perform, I consider as the most gratifying belonging to the office of your President. It is to announce to you, Gentlemen, the decision of your council, in awarding the medal of the Society, for the year 1822, on Sir Godfrey Copley's donation, to the Reverend William Buckland, your worthy Fellow, and professor of geology in the University of Oxford, for his account of the fossil teeth and bones, discovered in a cave near Kirkdale, in Yorkshire,

and published in the *Philosophical Transactions* for the present year.

This is the first time that a communication on a subject of pure geology has been honoured with so distinguished a mark of approbation; and from the merits of the communication, which has been for some time before the public, I am convinced you will think your council has performed an act of justice, and not of favour, towards the author.

It is not a little remarkable, that whilst the natural history of the heavenly bodies, so far removed from us, was the earliest object of scientific research, the mineral philosophy of the earth we inhabit, of the substances under our feet, has been the latest. The brilliancy of the celestial phenomena, their connexion with the seasons, and with the superstitions of the ancients; the facility with which mathematics were applied to their figures and motions, and their relations to time, rendered astronomy, in all ages and countries, a popular study; whereas the difficulty of penetrating into the strata of the surface of the globe, the apparent disorder and confusion of their contents, and the want of any scientific principles applicable to the subject, for a long while prevented geology from being numbered even among the sciences.

By the ancients, cosmogonies or dreams respecting the origin and changes of our planets, were substituted for actual observation; and though, in the early progress of general philosophical inquiries in Europe, particularly amongst the works of early Members of this Society, or contributors to the *Transactions*, such as Hooke, Lister, Holloway, Pococke, and Strachey, some general views were formed, and accurate histories of particular phenomena recorded; yet it is only within

the last half-century that the subject has been pursued, in the active spirit of research, by truly philosophical minds; and that it has been an object of general scientific attention.

At the beginning of this period, mineralogy offered a regular arrangement of fossil substances; and De Saussure, Pallas, and, above all, Werner, considering and perfecting it as the alphabet of geology, endeavoured to read, slowly and carefully, this interesting part of the Book of Nature. Chemistry, annually making a rapid progress, had not only explained the intimate nature of mineral bodies, and so afforded correct means of classing them, but likewise offered the powers of judging of their past changes, by analyses deduced from accurate experiments; and the comparative anatomy of plants and animals, in tracing and fixing the resemblances between existing beings, had furnished the links of inductive reasoning, by which the extinct species belonging to the mineral kingdom were to be examined and known.

Under such advantages it was to be expected that a rapid advance would be made in the science. Private and public museums have been formed in every part of Europe. Societies have been instituted for the express purpose of pursuing geological inquiry. Maps, in which the mineral history of districts and countries is laid down, have been published; and within the last twenty years, it is not perhaps unjust to say, that rational geology has made more progress than in all the preceding time.

In a discourse so limited in its object as that I am now delivering, it would be impossible to mention, even in the most cursory manner, the labours of those inquirers who have been most successful in this field of

science; but no one amongst them has been more distinguished, by ardour in the pursuit of knowledge, by success in geological discovery, and soundness in philosophical reasoning, than Mr. Buckland. His lectures, in the University of Oxford, have raised a numerous class of disciples, who are following his praiseworthy example in the pursuit of science; and his former publications equally proved his indefatigable spirit of research, his accuracy of observation, and his caution and sagacity in drawing conclusions.

Upon the nature of the paper which your council has considered as entitling him to the medal, I shall make a few observations. It has been probably read with interest by every one who is here present; I will not, therefore, attempt to analyse the details. I shall merely point out the particular fact that it establishes in the history of the globe, and which I consider as of great importance; but for this purpose it will be necessary to offer a few preliminary observations on the structure of the known part of our globe, and of the changes which it has undergone.

It has been ascertained, by the examination of a great extent of the surface, that the rocks which rise to the greatest elevation in the atmosphere, and those found at the lowest depths to which human industry has, as yet, penetrated, are composed wholly of crystalline matter, containing no remains of organized beings, or of any former order of things: upon these rocks, at common heights or depths, are found others, principally constituted of crystalline matter, and affording some few remains of shells, fishes, and plants. To these succeed a number of strata, or layers, less consolidated, affording much smaller proportions of crystals, abounding in fragments of the older rocks, and con-

taining imbedded in them, the remains of plants, shells, fishes, oviparous reptiles, amphibia, and birds; each stratum being characterised by the peculiarity of its organized remains.

Upon these consolidated and extensive strata are found others, which, when not produced by deposition of gypsum, in what may be called fresh-water formations, consist of clay, sand, gravel, or water-worn stones, and in these are discovered, amongst a vast number of other deposites, the remains of viviparous quadrupeds.

In the lowest strata, it has been observed, and I have found by experiments, these organized remains contain none of their original bony matter; but, in proportion as the formations or depositions may be supposed to be more recent, so in proportion is more of the original matter of the bone or shell found in them. The remains of the bones of the animals of the saurus or lizard kind, found in the limestone of Sussex or Dorsetshire, contain very little animal matter, but much phosphate of lime; those in the Kirkdale cave contain almost all their phosphate of lime, but have lost a considerable portion of animal matter: whilst the bones dug up at Trasimenè or Herculaneum differ very little from recent bones.

These remains of viviparous quadrupeds, found in the diluvian strata, most curious in their nature, appear to have belonged to animals which no longer exist. Cuvier, to whose genius we owe all the great elucidations of this mysterious subject, has found that amongst upwards of seventy varieties of animals, discovered in these strata, eleven only bear a perfect resemblance to species now existing, and by far the greater number belong to unknown species, and more than thirty to new genera; and it is remarkable that the species re-

sembling those which now inhabit only warm climates, are found in the fossil state in cold ones; the bones, and even the entire body and skin, of the elephant and rhinoceros, in Siberia; and the bones of elephants, hippopotami, hyænas, and animals of the tiger kind, in these islands and over the continent of Europe.

It has generally been admitted by sound reasoners, that the manner in which these bones are found buried amongst gravel, sand, and water-worn stones, proves the operation of a great diluvium — an inundation of the waters of the ocean over the land. But, till Professor Buckland's paper, there had been no decisive evidence, though there had been reasonable conjectures, that these animals once existed in the countries in which their remains are now found, and that they had not been transported by the violence of the inundation or of currents acting under very peculiar circumstances, from other climates, such as those now inhabited by the same species of animals.

As far as Yorkshire and England are concerned, and analogy would induce us to conclude, the whole of Europe and the northern continent, Professor Buckland has shown, by fair inductive reasoning, that a large species of hyæna, the rhinoceros, the hippopotamus, the elephant, and animals of the bear and tiger kind, once inhabited this country; and he infers, with some degree of probability, that they were destroyed by the deluge. Since Professor Buckland's paper has been published, I have had the pleasure of visiting the cave, in his society, and entertain no doubt of the general accuracy of his conclusions. The horizontal nature of the fissure,—the immense quantity of bones and teeth found in it, — the manner in which they are worn on one side, — the marks made by the gnawing of teeth in

many of them, — the excrements of the animal, — all prove the circumstance of the cave having been inhabited by hyænas, probably, by many generations; who brought in from the neighbourhood, such animals as they could destroy, or such as, found dead, they could tear into pieces.

You will, I am sure, consider it as a fortunate circumstance, that such a phenomenon occurred to so accurate an observer as Professor Buckland. The nature of the cavern rendered it inaccessible, except in quarrying the rock; fortunately it was closed by stalactite, and the bones were covered with mud, which prevented the action of the included atmosphere upon them, and, consequently, their decomposition: and thus they remained, almost in their primitive state and positions, sealed up, — a faithful record, as it were, of a past age of the world.

Since your last Session, Professor Buckland has examined various caves in different parts of Germany, containing bones; and the cavity in the limestone-rock at Oreston, near Plymouth; of which an account had been formerly published in your *Transactions*, and has confirmed his general conclusions, concerning the period at which the animals, to whom the bones belonged, lived, and their destruction by a great inundation of water. But I shall not anticipate his views, as I hope he will himself lay them before the Society.

The existence of animals, of genera now only found in warm climates, being established, it becomes a curious inquiry whether our temperature has been changed, or whether the difference in the species, and consequently the habits, was such as to enable them to live in temperate or cold climates. Professor Buckland, with his characteristic caution, has not decided on this

question. The ancient hyæna, elephant, and hippopotamus of this country were, perhaps, as different from those of Africa, as the musk ox is from the common ox; yet, supposing the antediluvian climate of Siberia, such as it is now, it is difficult to imagine that an animal of the elephant species could have found sufficient food there, or that a hippopotamus could have inhabited its frozen rivers.

It seems much more likely that the temperature of the globe has been changed; and perhaps suddenly, by a great irruption of water from a deep ocean over the land. An ancient high temperature of the globe, is likewise not only consistent with this view of the subject, but likewise with the late observations made on the heat of the interior, and with the facility afforded by it of explaining many existing phenomena, and many mineral productions. I shall not, however, indulge in any speculations on this subject, which no person is more capable of illustrating, than the worthy Professor himself.

I cannot conclude this part of my subject, without congratulating the Society that by these inquiries, a distinct epoch has, as it were, been established in the history of the revolutions of our globe: a point fixed, from which our researches may be pursued through the immensity of ages, and the records of animated nature, as it were, carried back to the time of the creation.

It is gratifying to feel that the progress of science establishes, beyond all doubt, the great catastrophe described in the sacred history, and the account of which is blended with the traditions of so many ancient nations; and that it likewise demonstrates the circumstance of a primitive chaotic state of the globe, in which there was no life, of a successive creation of living

beings, of which man was the last, destined to people the earth, when its surface had assumed a state of order and beauty fitted for the improvement and activity of an intellectual and progressive being.

In comparing such deductions of geology with some brilliant speculations of the last century, it is impossible not to smile at the aberrations of human genius, and to be proud of the progress we have made.

The eternal order of one simple system, in which the same beings, slightly changed, existed, and in which water is the destroying, and fire the renovating principle, though supported by so much talent, fact, and experiment, has disappeared, for the sound geologist, with the more visionary ideas of the earth's being originally a portion of the sun; and of organized germs passing, in the immensity of time, through the different stages of improvement, rising from fishes through mermaids, quadrupeds, and apes: and, at last, perfect in man!

Hypotheses and dreams of this kind are now rejected; and so ought to be all those views, in which systems of geology are attempted to be framed out of the sacred writings, by wresting the meaning of words, and altering the senses of things. Lord Bacon long ago raised his voice against this mode of proceeding: grand facts in the history of the globe are given, but not systems of philosophy. Man has no right to measure divine truths by his own fancies or opinions: they should be kept perfectly distinct. The more we study nature, the more we obtain proofs of divine power and beneficence; but the laws of nature and the principles of science were to be discovered by labour and industry, and have not been revealed to man; who, with respect to philosophy, has been left to exert these god-like faculties, by which

reason ultimately approaches, in its results, to inspiration.

MR. BUCKLAND,

Receive this medal, as a proof of the high estimation in which your labours and researches are held by a body which, I believe, is very impartial in its decisions, and which, I trust, looks to the actual progress science has made, rather than the person, school, or nation, to whom it has been owing. I know I need not urge *you* to a further pursuit of these inquiries, by which you have gained distinction, and so much merited popularity. You are, I am sure, devoted to them, and I only wish you health to enable you to pursue them; for I am convinced that the longer you live, the more extended will be the obligations you will confer on the world of science; I hope your example will stimulate some of the younger Fellows of the Society to similar researches. It is, as it was originally, *the Royal Society for the improvement of natural knowledge*; and we have been, and always are, most happy to receive important facts, laws, and principles respecting the mineral history of the earth. We deeply feel the use and the importance of such inquiries, in their relations to the progress of the arts, as well as to the sublimer speculations of philosophy. How intimately, for instance, is agriculture, on which nations depend for their powers of supporting and multiplying a happy population, connected in its progress with the knowledge of the nature of soils, of the sub-strata and strata of the earth, and of fossil manures! How much is architecture, next perhaps in utility, dependent for its resources upon an acquaintance with the nature and situation of stony substances, necessary for permanent structures, and those qualities

of them which occasion their decomposition, or their permanency! And how great a part of the actual strength, as well as the wealth of countries, depends upon their metallic and mineral veins and strata—upon their coal and their iron, which, applied by chemical and mechanical ingenuity, have, as it were, caused the elements to labour for man!

Nor is this study, as no one has better explained than yourself, without its moral benefits, affording happy views, where they might least be expected, of the economy of nature: the great mountain-chains equalizing the temperature of the globe, and, by their elevation, rendering warm climates habitable; the ocean being a reservoir of heat, and the rocky strata serving not merely as the support of soils, but causing a distribution of the water poured down from the atmosphere, for the purposes of vegetable and animal life. Then, in the history of the past changes of the globe, what a sublime subject is there for the exercise of the imagination!

If we look with wonder upon the great remains of human works, such as the columns of Palmyra, broken in the midst of the desert, the temples of Pæstum, beautiful in the decay of twenty centuries, or the mutilated fragments of Greek sculpture, in the Acropolis of Athens, or in our own Museum, as proofs of the genius of artists, and power and riches of nations now passed away; with how much deeper a feeling of admiration must we consider those grand monuments of nature, which mark the revolutions of the globe: continents broken into islands; one land produced, another destroyed; the bottom of the ocean become a fertile soil; whole races of animals extinct, and the bones and exuviæ of one class covered with the remains of another; and upon these graves of past generations, the marble

or rocky tombs, as it were, of a former animated world, new generations rising, and order and harmony established, and a system of life and beauty produced, as it were, out of chaos and death; proving the infinite power, wisdom, and goodness of the Great Cause of all being!

DISCOURSE OF THE PRESIDENT,

ANNIVERSARY, DEC. 1ST, 1823,

On the Characters of Dr. HUTTON, Dr. JENNER, Dr. BAILLIE, Colonel LAMBTON, Archdeacon WOLLASTON, Dr. CARTWRIGHT, and Mr. JORDAN; and on the Award of the Copley Medal to JOHN POND, Esq., Astronomer Royal, for his various Papers on Subjects of Astronomy, published in the Philosophical Transactions.—With General Views of the Present State of Astronomy, and on the Accessions made to this Branch of Science, in the Royal Observatory at Greenwich.

AFTER perusing this list of deaths I cannot avoid saying a few words on the characters of some of the Fellows whom we have had the misfortune to lose. Of course I can only speak of such as, by their communications to the Society or philosophical labours, have promoted the progress of science. Those who have other claims to public consideration will receive their applause in other places. Here a tribute of respect to the memory of the dead, who have promoted the objects of the Society, is called forth by gratitude, and it may perhaps awaken a feeling of emulation in the living.

The labours of more than half a century, Gentlemen, have established the reputation of Dr. Hutton, as one of the most able mathematicians of his country and his age.

His papers, published in the *Transactions* of the Royal Society on Converging and Infinite Series and Cubic Equations, and his elementary and original works

on various branches of the science of quantity, prove the extent of his knowledge, his industry, and his penetration. And, during the long period that he was Professor at Woolwich, he may be regarded as having eminently contributed to awaken and keep alive that spirit of improvement among the military students which has so much exalted the character of the British officer, and which has been attended with such beneficial results to the country. Dr. Hutton's merits, as an experimental philosopher, were of no mean kind, and they are displayed in his paper on Gunnery, for which he was rewarded with the Copley Medal, by the President and Council of the Royal Society, in 1778. In this paper he extends the views and inquiries of Robins by many difficult and delicate experiments on the force of gunpowder, and draws conclusions which have been connected with important practical results. But perhaps Dr. Hutton's greatest work was his calculation of the density of the earth, founded upon Dr. Maskelyne's experiments of the effect of the attraction of Schehallien on the plumb-line, in which a simple quantity was to be discovered by the most complicated arithmetical processes, and which required great devotion of time and labour. His name, on this occasion, will ever be associated with one of the grandest and most important physical problems solved in the last century, and will pass down with honour to posterity.

Dr. Hutton, as you well know, died at a very advanced age, and retained the vigour of his faculties. Nothing, indeed, can be a stronger proof of this than his paper communicated to the Royal Society in 1821, when he was eighty-four years of age, and which contains a comparison of Dr. Maskelyne's and Mr. Cavendish's experiments on the density of the earth, and a

number of corrections of very difficult and intricate calculations.

To speak of Dr. Edward Jenner as a man of science of our own particular school, would be saying little; he has a higher claim to our deep regret and profound admiration, as a benefactor to mankind in general.

It is needless for me, Gentlemen, to dwell upon the effects of vaccination, but I may say something of the nature of the discovery. It often happens, that when, by enterprise, ingenuity and unwearied application to one train of thought or experiment, some great step is made in practical or theoretical science, persons of common minds, in considering the simplicity of the result, are apt to undervalue the labour by which it was attained, and to refer to accident what has been really effected by the highest operations of the human understanding. That persons who had passed through a certain disease, communicated by cattle, were not liable to variolous infection, had perhaps been known amongst the vulgar for more than a century; but without the investigation of Jenner, this knowledge would have remained hidden from the scientific world, and perhaps been regarded as a vulgar prejudice. Lord Bacon has said, "there are short methods for men of genius;" but it might, perhaps, with more propriety be said, there are *new* methods for men of genius. Their characteristic is, that they do not walk in beaten roads, and that in seeing an object before them, they are neither deterred by danger or the fear of ridicule, from following it through unfrequented paths. The originality of Dr. Jenner's mind and his accuracy ot observation, are shown in his first communication to the Royal Society, on the natural History of the Cuckoo; and, in pursuit

of his great object, he met with obstacles which it required no ordinary degree of perseverance and of confidence in his own powers to overcome.

The fair way of judging of the merits of an inventor, is by the operation of his discovery in civilized and social life: and, in this respect, Dr. Jenner stands almost alone, having subdued a positive evil, having secured a benefit not only for all the present inhabitants of the earth, but for their most remote posterity: gaining for his name the most enviable kind of immortality, that connected with the gratitude and blessing of his fellow-creatures, and which will be more valued in proportion as men estimate more correctly the nature of true glory.

It is difficult, in speaking of those with whom we have been connected by ties of friendship, whom we have admired and reverenced, to be strictly impartial; yet I believe that the merits of Dr. Matthew Baillie can hardly be estimated too highly, even by those who had the warmest feelings of affection for his memory. Whether considered as a physician or as a man, his talents and his virtues were alike distinguished. His works show the accuracy and coolness of his judgment, his minuteness of observation, and his acuteness in referring effects to their true causes, amidst the complicated phenomena offered by diseased organs. Whoever heard him give his opinion in the Council of the Royal Society, was struck by the clearness and simplicity of his details, and the happy manner in which he caught the relations and explained the nature of a scientific subject in which he was interested.

Those who have seen him by the bed-side of the sick, who witnessed the kindness of his nature, the deep interest that he took in the sufferings and danger

of his patients, will, above all, estimate the nobleness and disinterestedness of his conduct. An honour to his profession in public life, he was most amiable and exemplary in his intimate social relations and domestic habits. No man was ever freer from any taint of vanity or affectation. He encouraged and admired every kind of talent, and rejoiced in the success of his contemporaries. He maintained, even at court, the simplicity and dignity of his character. His greatest ambition was to be considered as an enlightened and honourable physician. His greatest pleasure appeared to be in promoting the happiness and welfare of others.*

With respect to Colonel William Lambton, a veteran in the army of India, and who was personally known to very few Fellows of the Society, I can speak only of his works, and refer you to the two papers published in the *Transactions*, on the Admeasurement of an Arc of the Meridian in Hindostan, a work of great labour, displaying minute accuracy and extraordinary perseverance, and carried on in a climate unfavourable to bodily exertion or intellectual pursuit. This arc extends in amplitude nearly 10°, upwards of 9° 53′, from

* [There never was a man, I believe, more respected by his professional brethren; a strong proof of moral excellence, as well as of high attainments. The last time I ever saw Dr. Baillie, proof was given of this feeling; it was, when in a valetudinary state, not many months before his death; it was at a large meeting of medical men, amongst whom were some of the most distinguished of the metropolis. Owing to his infirm health Dr. Baillie rose from table early in the evening; there was a spontaneous rising of the whole company, and before he could quit the room his health was drank with acclamations, and in such a manner as to affect him sensibly, as was very apparent from the tremulous tones of his voice in his reply to the compliment. Never before or since have I witnessed such a demonstration of professional respect.]

Cape Comorin to Namthabad; and Colonel Lambton has the honour of having laid down the largest connected portion of the meridian ever measured upon the surface of the globe; a work not only of importance in its relation to the figure of the earth, but constituting the foundation for a correct survey of our extensive possessions in India.

Of Archdeacon Wollaston, whose recent and sudden death has occasioned so much affliction to his family and friends, I can only say, that the little he communicated to the Royal Society makes us feel regret that he was not a more frequent contributor to our *Transactions.* His paper on the Measurement of Heights, by the Alteration of the boiling Temperature offers a valuable resource in ascertaining the altitude of mountains, and is remarkable for accuracy of method and distinctness of detail. I have always understood, that as a Professor in the University of Cambridge, his lectures were admirable; and he was worthy of a family in which talents and virtues seem to be hereditary.

Dr. Cartwright became a Fellow of the Society late in life. He was a very amiable man, possessed of literary talents, much mechanical ingenuity, and great enthusiasm in the exercise of it: and he received a parliamentary reward for a mechanical invention which, I believe, has been of considerable use to the manufactures of the country.

Mr. Jordan was attached to science, and pursued with ardour a branch of optics, on which he published a work; he had the merit of attending to philosophical

subjects amidst the duties of a profession which is rarely associated with scientific habits. No communications either of Dr. Cartwright or Mr. Jordan have been published in your *Transactions*.

COPLEY MEDAL.

From the melancholy office of speaking of the merits of your deceased Fellows, I now pass to the more pleasing duty of stating the useful labours and active exertions of a living philosopher.

Your Council, Gentlemen, have awarded the medal of Sir Godfrey Copley's donation, for the year 1823, to John Pond, Esquire, Astronomer Royal, for his various papers and observations communicated to the Royal Society.

The merits of Mr. Pond, as an indefatigable scientific observer, are fully and justly estimated by all the Fellows of this Society, who have visited or taken any interest in the Royal Observatory; but, perhaps, the early devotion of the Astronomer Royal to his favourite science, the enthusiasm with which he pursued it, and the sacrifices of time, health, and money that he made in consequence, may be less generally known.

Twenty-five years ago, Mr. Pond, animated by his love of astronomy, carried, at a considerable expense, some valuable instruments to the coasts of the Mediterranean, hoping that a purer atmosphere and a brighter sky would give him advantages for pursuing continued observations on the fixed stars, not to be obtained in the variable climate of this island, and he passed some time devoted to his scientific objects at Lisbon, Malta, and Alexandria; but the state of his health obliged him to return, and he established himself at Westbury,

in Somersetshire, where, in 1800, I had the pleasure of visiting him, and when I was delighted to witness the ardour with which he pursued his inquiries; and saw with admiration, the delicacy of his observations with the astronomical circle of Mr. Troughton's construction.

The researches made at Westbury, by Mr. Pond, on the declinations of some of the fixed stars, in 1800, and published in the *Philosophical Transactions* for 1806, fixed the attention of astronomers by their accuracy and the clearness of the details; and probably principally caused those scientific recommendations which inclined our august Royal Patron, then Prince Regent, to appoint him to the distinguished office which he now holds.

Since Mr. Pond has been Astronomer Royal, his communications to the Royal Society have been numerous, and many of them of great importance.

I shall mention some of the most considerable :—

In 1813, A Catalogue of the North Polar distances of thirty-four of the principal Fixed Stars, deduced from Observations made with the Mural Circle, at the Royal Observatory.

In 1815, Determination of the North Polar Distances, and proper Motions of thirty Fixed Stars.

In 1817, Three Papers on the Parallax of the Fixed Stars.

In 1818, On the different method of constructing a Catalogue of the Fixed Stars: on the Parallax of *α* Aquilæ, and on the Parallax of the Fixed Stars in right Ascension.

In 1823, Three Papers on the Changes that have taken Place in the Positions of some of the Fixed Stars, and a Paper on the Parallax of *α* Lyræ.

It is very difficult, or almost impossible to point out the specific merits of astronomical observations. They are not like philosophical or chemical experiments, which produce an immediate result; their delicacy and exactness can only be judged of by persons who have seen the manner in which they are made, and who are accustomed to the same kind of labour. They often relate to long periods of time, and their correctness and value can only, perhaps, be fairly estimated by posterity.

The two principal points of discussion in these papers of the Astronomer Royal, are, the grand and long-agitated question of the parallax of the fixed stars, and an apparent declination or change of position in a number of the stars, not to be accounted for by any known laws.

Since the Copernican system was first received as the true system of the universe, by the enlightened philosophers of Europe, the inquiry, whether the fixed stars had any annual parallax, has been constantly brought forward.

It was evident that the diameter of the earth would not afford any difference of angle with bodies so immensely distant as the stars, but it was hoped, that such a difference would be observed at the two extremities of its annual orbit, distant from each other nearly one hundred and ninety millions of miles.

Flamstead supposed he had observed a considerable annual parallax; but the observations of Bradley proved that the phenomena which he described were owing to another cause, and he solved them by his grand discovery of the aberration of light. The subsequent observations of Bradley, with the great sector constructed by Graham, the instrument that he had likewise used in his former researches, led to no result favourable to

parallax; and the minute and accurate observations of the late Astronomer Royal were on the same side of the question.

Between 1800 and 1806, Piazzi imagined that he had proved a parallax of some seconds, and Dr. Brinkley, in 1810, communicated through Dr. Maskelyne, his observations on *α* Lyræ, made with the great eight-feet Dublin circle, and which, he conceived, showed that the parallax of that star could not be less than 2″ or 2½″. This star, and other stars, have been observed with great accuracy, by Mr. Pond; and his conclusions, both from the use of a fixed instrument, and of the great circle, are, that none of the fixed stars, which have come under his observation, have any sensible parallax, and that the parallax of *α* Lyræ, if it exist at all, cannot exceed a very small fraction of a second; his general conclusions are thus stated by himself: "The observations of this year have produced on my mind a conviction approaching to moral certainty. The history of annual parallax seems to be this—in proportion as instruments have been imperfect in their construction, they have led observers into the belief of sensible parallax: this has happened in Italy to astronomers of the very first reputation. The Dublin instrument is superior to any of a similar description on the Continent, and, accordingly, it shows a much less parallax than the Italian astronomers imagined they had detected.

"Conceiving that I have established, beyond a doubt, that the Greenwich instrument approaches still nearer to perfection, I can come to no other conclusion, than that this is the reason why it discovers no parallax at all."

Dr. Brinkley has not yet replied to Mr. Pond's latest examination of this subject; but in an elaborate paper, published in the *Transactions* for 1821, he enters into a

full discussion of the question, and displays, as usual, the most profound views of the causes which may affect his observations, and the greatest acuteness in examining the objections that have been made to his conclusions, and he endeavours to confirm them by new observations, and is still of opinion, that many of the fixed stars have a sensible parallax. In awarding the medal to Mr. Pond, the Council of the Royal Society do not at all mean to express an opinion on this subject: when two such astronomers differ, it would be presumptuous, and almost impossible, for them to decide; it is, however, highly satisfactory to know that the question is now reduced within such very small limits, the difference between the Greenwich and the Dublin observations generally amounting to less than a second. Those who read Dr. Brinkley's and Mr. Pond's papers with attention, can alone judge of the refinements of modern observation, and of the perfection to which the genius and labour of Mr. Troughton have carried our instruments, and of the extreme difficulty and delicacy of this investigation, in which the smallest differences of temperature, and (when stars are not in the zenith) of the refractive power of the atmosphere, produce immense results, and where perfect stability of the instrument of the building, and of the ground on which it stands, are absolutely essential.

With respect to the second great point in Mr. Pond's papers, the apparent variation in the position of many of the fixed stars; the novelty of the subject and the great importance of its relations, and the very short time that has elapsed since it has been brought before the Society, and the necessity for its confirmation by the observations of a long series of years, so as to discover the true cause, render it impossible for me to do

more than state the supposed result, and the manner in which it was obtained.

You will well remember the candour with which the Astronomer Royal communicated to the Society the account of an accident which had happened to the mural circle. In examining the supposed errors in the places of fixed stars owing to this accident, he at first rated them high; but after the instrument was put in a state of perfect repair, he found, by the most delicate observations, that a part of what he considered an error, appeared to be really owing to a southern declination of many of the principal fixed stars, and that their real places were considerably further south than their predicted places, as discovered by ancient catalogues. After considering the subject under every point of view for more than twelve months, and examining the most correct catalogues, the Astronomer Royal is still of the same opinion on this subject, and he considers this apparent change in the position of the principal fixed stars, as incapable of being accounted for from any source of error in the instrument or mode of observation, and as pointing out to some unknown and new principle. However improbable this may at first view appear, it will be recollected by the Fellows of this Society, that the first germs of the great discoveries of Bradley,—the Aberration of Light, and the Nutation of the Axis of the Earth,—were observations of this kind, but nearly a quarter of a century was required for the full development of these grand truths.

Should the southern declination be ultimately established, a motion towards, or slow revolution of the sun round some part of the sidereal world, seems a much more probable cause of explanation than any new unexplained relations of the system to light, or any un-

known motion of the axis of the earth, or any proper motion, in one direction, of the great body of the stars. But these are points for future discussion, upon which no man is more able to enter than the Astronomer Royal himself; let us hope that he will verify, and place beyond doubt, this important but still uncertain result, and that it will lead to a new law in nature, and add another important discovery to those which we already owe to the labours carried on in the Royal Observatory, and which have so much contributed to the progress of astronomy, and to the glory of our country.

I cannot touch upon this subject without saying a few words more, for it is one which ought to call forth feelings of gratitude and admiration in every Fellow of this Society.

How distinctly the results obtained there prove the utility, almost necessity, of the foundation and the patronage of some such establishments by government; for since the existence of this noble Institution, what lasting benefits has it conferred on science and the public!

I remember the late excellent Secretary* of the Royal Academy of Sciences at Paris, said to me, in conversation ten years ago, "Such is the excellence and extent of the Greenwich observations, that if all the other records of science were destroyed, they alone would be sufficient to found a system of astronomy."

In going back to Flamstead's time, we find them taken by all Europe as the models to be followed in similar establishments. Of Halley, a philosopher of a higher stamp, and inferior, perhaps, only to his friend and master, Newton, it is scarcely possible to speak

* [M. Delambre.]

with sufficient praise. The observations of the transits of Venus, the determination of the solar parallax, the investigation of the Newtonian law of cometary motions, and the prediction of the return of the comet of 1682, in 1759, the foundation of the method for observing the lunar motions, and the accurate observations of that satellite for more than nine years,—labours which have led to the construction and perfection of those tables which are of such immense importance to navigation, and which may be said to have given us the discovery of the longitude at sea,—are a few amongst the obligations of astronomy to this great man.

Of Bradley, it may with truth be said, that he was worthy to succeed Halley, and his name is immortalized by the two most important discoveries ever made with respect to the system of the heavenly bodies.

Of Dr. Maskelyne, whom we remember with so much respect and affection, it is only necessary to say, that his was a kindred spirit to that of those illustrious philosophers; and whether determining the density of the earth in his shed on Schehallien, or observing the fixed stars with unwearied attention at Greenwich, he was always the same patient, acute, sagacious, and unprejudiced observer.

Without an establishment provided by the liberality of government, without that retirement and philosophic leisure afforded by their situation, without instruments requiring an expense which few individuals can command, these distinguished men might almost have been born in vain; and what a recompense has been bestowed on the nation, for the few hundreds of pounds annually devoted to this object! The greatness of this country has arisen with its maritime and colonial empire; and how much has the Royal Observatory done

for the perfection of navigation, and the interests of our navy! A misfortune like that, by which one of our noblest fleets and bravest admirals were lost on the rocks of Scilly, not much more than a century ago, can now never happen again; and, independent of the common question of utility, what an immense effect has the progress of astronomy, following and confirming those views of the system of the universe of our own illustrious Newton, had upon the improvement of general science, thus enlightening and exalting the human intellect! All the superstitious notions, all the prejudices respecting the heavenly bodies, which had such an effect upon the destinies of individuals, and of kingdoms in ancient times, have disappeared. Man, acquainted with his real situation in the scale of the universe, has learned to appreciate his objects, and the ends of his creation. A mere drop in the ocean of infinity, he has yet sufficiently felt his divine and intellectual nature, to elevate his mind from the minute base of the earth to the heavens, to investigate the laws of bodies invisible to him, except by instruments of his own invention, and hundreds of millions of miles removed from him. And, in the progress of his knowledge, he has seen obscurity vanish, motions which, considered for a short space of time appeared disorderly, he has found belonging to an extensive and regular cycle; and in what seemed sources of confusion and imperfect machinery in the constitution of things, as new lights have poured in upon him, he has found causes of order and harmony. So that modern astronomy, as it now exists, is the noblest monument ever raised by man to the glory of his Maker: for its ultimate and refined developments demonstrate combinations which could only be the result of infinite wisdom, intelligence, and power.

MR. ASTRONOMER ROYAL,

I now present to you this medal, as a token of the respect of the Society, and of the confidence of the Council, in the great accuracy of your observations, and likewise as a memorial that future important labours in the same department of science are hoped for, nay expected, from you.

I am well aware, that some of the greatest and most important objects of discovery, and those perhaps most obvious, have been obtained by the labours of your predecessors, and that in proportion as the field is investigated, new results become rare, as well as more difficult to be discovered; yet nature is inexhaustible, and the powers and resources of the human mind, and the refinements of art, have not as yet attained their limits. Who would have anticipated, half a century ago, the discoveries of Herschel and Piazzi?—Though pursuing a science that may be considered as in its maturity, you have advantages of a peculiar kind, more perfect instruments than were ever yet employed, more extensive assistance than any of your predecessors; and upon these points, the liberality and promptitude with which Government have entered into your views, and those of the Council of the Royal Society, for the improvement of the Royal Observatory, cannot be too much admired. Continue to pursue your honourable career, and endeavour to be worthy of having your name transmitted to future generations with those of your illustrious predecessors.

Of all the branches of science, astronomy is that from which this Society has gained most glory; and it never has lost, and I am convinced never will lose, any opportunity of advancing its progress, and honouring its successful and zealous cultivators.

DISCOURSE OF THE PRESIDENT,

Anniversary, 1824.

Character of Baron Maseres.—Award of the Copley Medal to the Rev. Dr. Brinkley, now Bishop of Cloyne, for his Mathematical and Astronomical Papers published in the Philosophical Transactions.—With Views on some Refined Questions of Astronomy, and on the General Importance and Sublime Views of this Science.

In reading over this list, though there is one person of extraordinary genius,* still an object of deep interest in the literary world, and though other names occur connected with useful professional labours, yet the only character which I am called upon to notice, as a contributor to your *Transactions*, and as an active scientific member of the Society, is that of Baron Maseres. He may be considered as belonging to the old mathematical school of Britain; and through a long life devoted much of his leisure and a portion of his fortune, to the pursuit and encouragement of the higher departments of algebra and geometry. Four of his papers are published in your *Transactions*, — two on Infinite Series, and two on the Extension and Discovery of Cardan's Rule. He printed, at his own expense, the *Scriptores Logarithmici*, and an extensive and laborious work on *Negative Quantities*, in which he took a very peculiar view of this abstruse subject. He was fonder of investigating the principles of the mathematical sciences, than of attempting applications of them. His love of

* Lord Byron.

science was of the most disinterested kind, as is shown by the nature of his publications, and by the liberal way in which he encouraged the publications of others. He died in extreme old age, having almost outlived his faculties.

COPLEY MEDAL.

In following the course of the business of the day, I have to announce to you the decision of your Council with respect to the medal of Sir Godfrey Copley's donation to the Society.

It has been awarded this year to the Reverend John Brinkley, D.D. Andrew's Professor of Astronomy in the University of Dublin, and President R.I.A., for his various communications printed in the *Philosophical Transactions.*

To some of the members of the Society, who have not followed closely the usages of the Council, a question might at first sight arise upon the decision, why in two successive years the cultivators of a science, which, during that time, has been distinguished by no remarkable discoveries, should receive the highest honours which this Philosophical Association has to confer.

A very short explanation will, I trust, suffice. The progress of science has no annual periods; and when a medal is to be bestowed every year, not merely important scientific facts, but likewise trains of useful labours and researches must be considered; and the zeal, activity, and knowledge of those persons, who, having been contributors to your *Transactions*, must be regarded as competitors, are to be taken into the account.

It has now and then happened that the Royal Society

has had the felicity to mark some great and brilliant discovery, such as that of the aberration of light, or the magnetic effects of electricity, by this token of its respect; but in general, of necessity, the medal is bestowed for contributions of a more humble character. To reward those laborious philosophers who enlighten science by correct observations or experiments, or those sagacious inquirers who by accurate reasonings or ingenious views, lay the foundation for new researches, new theoretical arrangements, or applications of science to the uses of life; and if any one department of natural knowledge requires encouragement more than another, it is astronomy; for having arrived at a mature state, and presenting few striking objects of discovery, it can only be perfected by the most minute, laborious, and delicate inquiries, which demand great attention, great devotion of time, and which must often be carried on at a period usually destined to repose, and often with the sacrifice of health.

Whoever considers these circumstances will, I am convinced, be satisfied of the justice of this vote of your Council.

Dr. Brinkley has long been known as an enlightened and profound mathematician. His labours, published in the *Memoirs of the Royal Irish Academy*, contain abundant proofs of his skill in the higher departments of analysis, but it is not necessary to look any where else for a demonstration of this, than in our own *Transactions*. The volume for 1807 contains an important paper, on the General Term of a Series in the Inverse Method of finite Differences; in which, taking up a subject of investigation on which both La Grange and La Place had written, he has surmounted a difficulty which had remained even after the investigations of these illustrious geometers.

Whoever is in possession of the higher resources of the mathematical sciences, may be considered as gifted with a species of power applicable to every department of physical knowledge. It is indeed for this species of knowledge, what muscular strength is for the different branches of human labour; it not only generalizes the results of experiment and observation, but likewise corrects them, and leads to new and more refined methods of investigation. The guide of the mechanical and pneumatical philosopher, and the useful assistant of the chemist, it is of still more importance to the astronomer, whose results depend entirely upon magnitude, time, and motion.

Endowed in so high a degree with one of the essential characters of an accomplished astronomer, his various later communications to the Royal Society, show that Dr. Brinkley is equally distinguished as a laborious, acute, and accurate observer. Your *Transactions* contain seven of his papers, on pure astronomical subjects: —

The first, On the Parallax of α Lyræ.

The second, On the Parallax of certain Fixed Stars.

The third, The Results of Observations made at the Observatory of Trinity College, Dublin, for determining the Obliquity of the Ecliptic, and the Maximum of the Aberration of Light.

The fourth, An Account of Observations made with the eight-feet Astronomical Circle since the beginning of 1818, for investigating the Effects of Parallax and Aberration on the Places of certain Fixed Stars; also the Comparison of them with former Observations for determining the Effects of Lunar Nutation.

The fifth, On the Elements of the Comet seen by Captain Basil Hall at Valparaiso.

The sixth and seventh, two papers communicated in the last year, — the first, On the North Polar Distances of the principal Fixed Stars, — the second, Additional Observations on the Parallax of α Lyræ.

On the high merits of these communications, there is, I believe, but one opinion amongst competent judges, not merely at home, but (I can speak from my own immediate knowledge,) likewise abroad.

Dr. Brinkley has taken up no difficult object of research, without first satisfying himself of the correctness of his instruments by numerous preliminary and delicate trials. He has likewise, in forming his conclusions, examined with philosophical precision all the circumstances which may interfere, and he states the results with the utmost candour, creating difficulties for himself, and proceeding with the greatest caution in these fields of inquiry which had been already entered in vain by so many illustrious men.

You well know, Gentlemen, that Dr. Brinkley and the Astronomer Royal are at issue on two great and leading questions of Astronomy — first, the sensible parallax of some of the fixed stars, — and secondly, on the apparent southern motion or declination of parts of the sidereal system. You know that sensible parallax is denied by Mr. Pond, and believed to exist by Dr. Brinkley; that, on the contrary, the southern declination is denied by Dr. Brinkley, and believed to exist by Mr. Pond.

I mentioned, in announcing the award of the medal last year, that the Council of the Royal Society had no intention of giving its sanction to the opinions of the Astronomer Royal, or of attempting to decide on these important and difficult questions. I again feel it my duty to make the same reservation on this occasion, and

to state that the general labours of Dr. Brinkley, on the most difficult parts of astronomy, and the approximation to the solution of a great problem, and the high merits of his philosophical inquiries, are the sole grounds on which the Copleian medal has been bestowed.

The Council could not with propriety form an opinion on these subjects, when two such astronomers, possessing such peculiar qualities for observation, and such varied and exalted resources, are at variance; and the difficulty and delicacy of the questions, will perhaps be fully perceived by the addition of some short details to those given last year on these obscure branches of sidereal astronomy.

When Copernicus first developed that sublime system of the planetary worlds which has since been called after his name, he was obliged to suppose the fixed stars at an almost infinite distance; and the astronomical instruments of that day offered no means even of attempting the discovery of their parallax. The importance of such a discovery was, however, immediately felt, as a demonstration of it would, in fact, become likewise an absolute demonstration of the Copernican system of the universe.

Galileo seems to have suggested the method of inquiry for parallax, by examining the relative position of double stars, at the two extremities of the earth's orbit; a method founded on the supposition that the stars differ greatly in distance. This method, likewise strongly recommended by Dr. Wallis, was first, I believe, practised and pursued with great sagacity and industry by Sir William Herschel: and though it has furnished many important results, with respect to the proper motions of their stars, and the arrangement and groups of these heavenly bodies, it has as yet afforded

no observations forming data for reasoning on the distance of the fixed stars from the sun.

The other method, and that which has been most insisted upon, seems likewise to have originated with the illustrious Florentine philosopher, that of observing stars about the summer and winter solstice in or near the zenith, for the purpose of avoiding the errors of refraction, by fixed instruments. The celebrated Robert Hooke, who erected at Chelsea a telescope thirty-six feet long, for examining γ Draconis, imagined that he had discovered a very considerable parallax for this star, but Hooke's observations were contradicted by those of Molyneux. Flamstead drew a similar conclusion from his experiments on the pole-star, but the results which he ascribed to parallax, were explained by Bradley's great discoveries of the aberration of light, and the nutation of the earth's axis; and it is remarkable that Hooke reasoned correctly on inaccurate observations, while Flamstead formed wrong conclusions from exceedingly correct results.

James Cassini, in observing Sirius, attributed a parallax of six seconds to this star; and La Caille, from observations made at the Cape of Good Hope, supposed it four seconds.

Piazzi, in researches pursued from 1800 to 1806, supposed that several of the fixed stars exhibit parallax. He assumes for Sirius nearly the same parallax as La Caille; for Procyon, three seconds; for Capella, less than a second. His conclusions are, however, given with great diffidence, and his object seemed to be, rather to call the attention of astronomers to a subject which had been for some time neglected, than to press his opinions upon them with any thing like confidence.

In all these observations made upon the stars, it must

be confessed nothing like southern motion, had ever been suspected.

Dr. Brinkley, in his first communication to the Royal Society on Parallax, in 1810, rated it for *α* Lyræ, at two seconds and a half. The Astronomer Royal, in endeavouring to confirm this result, has had no satisfactory indications of such a fact; and his general conclusions, as you know, both from observations made with a fixed instrument, and with the mural circle, are unfavourable to the existence of sensible parallax for any of the fixed stars; and he refers apparent parallax to the imperfection of the instrument with which the observations have been made, and offers, as a proof, the diminution of the indications, in proportion as instruments have become more delicate; and estimating the Greenwich as superior to the Dublin circle, thus accounts for the difference of his results and those of Dr. Brinkley.

This gentleman, in his last three papers on Parallax, has replied to all the arguments, and has endeavoured to overturn all the objections of the Astronomer Royal. He does not allow the superiority of the principle of the Greenwich instrument; and he shows the consistency of the Dublin instrument with itself, by thirteen summer solstices, for which observations on eighty-seven days were made, and which give the maximum of lunar nutation 9″.60, exactly what he had used for the sun, and very nearly the same result as that from the stars; placing the permanent state of the instrument beyond all doubt. The results of two hundred and sixty-two observations on *α* Lyræ, in 1811, give the mean difference between the summer and winter zenith distances at 1″.32; and repeated observations made in the last ten years, give sensible parallax, though with less consis-

tency, for α Aquilæ, α Cygni, and Arcturus, but none for γ Draconis.

The minute accuracy with which Dr. Brinkley has investigated the subject, can only be estimated by accomplished mathematicians and astronomers. He has examined all Mr. Pond's results, reasoning upon the law of the aberration of light, the effects of refraction, and of differences of temperature, and has compared his own series of observations with those of other astronomers, and he seems entirely convinced of the accuracy of his general conclusions. If any circumstances depending upon change of temperature, flexion of the instrument, or other causes of error existed, "Why," he says, "should they not be general for all the stars?" "Why," he asks, "should such causes exist for α Lyræ, and not for the pole-star, which shows no sensible parallax?"

In his last paper, he makes some further corrections in the co-efficient of aberration and solar nutation, and his ultimate result is $1''.14$ for the annual parallax of α Lyræ.

On the question of southern motion, Dr. Brinkley expresses himself with much more confidence than on that of parallax. He compares M. Bessel's, Mr. Pond's, M. Piazzi's, and the Dublin catalogues; and after endeavouring to prove a discordance in the Astronomer Royal's mode of applying the data in these catalogues to the question, he says, "from the weight of external testimony adduced, it will, I think, be readily conceded to me that the southern motion does not exist, and that it must be regarded as an error belonging to one or both of the Greenwich catalogues of 1813 or 1823."

Such is the state of these two questions.

They are not, however, questions of useless contro-

versy, or connected with hostile feelings. The two rival astronomers seem equally animated with the love of truth and justice; and have carried on their discussions in that conciliatory, amicable, and dignified manner, which distinguishes the true philosopher. I cannot give a stronger proof of this, than in stating that the Astronomer Royal was amongst the first of the Members of the Council to second and applaud the proposition for the award of this day.

I have said that these questions are not questions of useless controversy, nor are they questions of mere curiosity. No important changes can take place in the sidereal system, without affecting the whole of astronomy: the fixed stars are, indeed, to space in the heavens, what land-marks, or the extremities of base lines, are to distances upon the earth; and all our conclusions upon the great problems of the system of the universe, have been formed upon the idea of the general permanency of their arrangements.

With respect to parallax, it is not a little remarkable that Dr. Bradley, from his varied and refined observations with Graham's sector, concluded that α Lyræ could not possess a parallax of as much as 2″, and that Dr. Brinkley's conclusions, from his most refined observations, come far within these limits. Mr. Mitchell, likewise, from photometrical considerations, concludes that if the largest fixed stars are the nearest, and about the size of the sun, their parallax, taken from the quantity of light they emit, cannot much exceed one second; and Mr. Gauss, in a conversation that I had with him this summer, informed me that he had drawn a similar conclusion, from ascertaining the distance and size of the image of the sun upon the helioscope; the new instrument that has been used with so much success in triangulation.

There is one circumstance which seems to have perplexed Dr. Brinkley a little, namely, that some of the smaller stars seem to show a greater parallax than those of a larger apparent size: this, at first sight, might appear to throw some doubt upon the results; yet it, perhaps, admits of explanation, on the idea that if the stars are disposed in groups or systems as Mr. Mitchell and Sir William Herschel believe, the bodies possessing the greatest masses, may be in the centre of these groups, and the smallest stars in consequence most contiguous to the largest. It is to be regretted, that on the subject of parallax, no star has yet been observed absolutely in the zenith, which might easily be done in a part of the globe, for instance, under the equator, when almost precisely the same circumstances of temperature, moisture, and pressure of the atmosphere, would constantly exist. An instrument fixed on granite, or an aperture made in a solid stratum of rock, would destroy the probability of interference from foreign causes, and reduce the problem to the simplest possible conditions.

In waiting for new elucidations on these important questions (and no persons are more capable of giving them than the two distinguished astronomers now engaged in the discussion,) I cannot but congratulate the Society, that the state of scientific inquiry, and the number of scientific men, render it scarcely possible that any great problem can long remain unsolved, any considerable object of interest uninvestigated. No question is now limited to one observatory, to one country, or even to one quarter of the globe. While such men as Brinkley observe at Dublin, Bessel at Konigsberg, Arago at Paris, Olbers at Bremen, Schumacher at Altona, and Gauss and Harding at Gottingen, astronomy

must be progressive, her results cannot but become more refined.

The observatories established by enlightened public patronage, at the Cape of Good Hope, and by private munificence at Paramatta, in New South Wales, cannot fail of giving us almost a new sidereal world in the southern hemisphere. Already, Sir Thomas Brisbane has sent to the Royal Society an extensive catalogue; and we may expect everything from him that indefatigable zeal, ardour of pursuit, and intense love of the science can afford.

With the increase of the popularity and the means of astronomy, facilities for procuring the necessary instruments, have likewise been greatly increased; and it must be a gratifying circumstance to the lovers of science to know, that even on the Continent, extensive and accurate researches meet with no obstacle from the want of proper apparatus; and though Germany cannot boast of a Ramsden, a Troughton, or a Dollond, yet it possesses a Reichenbach, and a Fraunhofer, whose instruments even the Astronomer Royal, I am sure, would examine with pleasure.

All these circumstances ought to be subjects of congratulation to us, not of uneasiness; and if they produce any strong feeling, it should be that of emulation and of glory; the desire of maintaining the pre-eminence which, since the foundation of the Royal Observatory, has belonged to us in this science. And, amongst the cultivators of the different branches of human knowledge, astronomers particularly, whose subject is the heavens, should be above the feelings of low, or even national jealousy: their results are for all nations, and for future ages, and they require even for their perfection, the peaceful co-operations of philosophers in the remote parts of the globe.

I cannot give a more happy instance of this, than the manner in which the comet, of the shortest known period, of M. Encke, was observed by Sir Thomas Brisbane's assistants, in New South Wales, and the calculations of its return so fully verified.

There is no more gratifying subject of contemplation than the present state and future prospects of astronomy; and when it is recollected, what this science was two centuries ago, the contrast affords a sublime proof of the powers and resources of the human mind. The notions of Ptolemy of cycles and epicycles, and the moving spheres of the heavens, were then current. The observations existing were devoted rather to the purposes of judicial astrology, than to the philosophy of the heavenly bodies, to objects of superstition, rather than of science.

If it were necessary to fix upon the strongest characteristic of the superiority of modern over ancient times, I know not whether the changes in the art of war, from the application of gunpowder, or in literary resources, from the press, or even the wonderful power created by the steam-engine, could be chosen with so much propriety as the improved state of astronomy.

Even the Athenians, the most enlightened people of antiquity, condemned a philosopher to death for denying the divinity of the sun; and it will be sufficient to mention the idolatry and utter ignorance of the other great nations of antiquity, with regard to the laws or motions of the heavenly bodies.

Take the most transient and simplest view of the science, as it now exists, and what a noble subject for contemplation! Not only the masses and distances of the sun, planets, and their satellites are known, but

even the weight of bodies upon their surface ascertained, and all their motions, appearances, and changes predicted with the utmost certainty for years to come, and even carried back through past ages to correct the chronology, and fix the epochas in the history of ancient nations. Attempts have been made to measure the almost inconceivable distances of the fixed stars: and, with this, what sublime, practical, and moral results! The pathless ocean navigated, and in unknown seas, the exact point of distance from known lands ascertained. All vague and superstitious notions banished from the mind, which, trusting to its own powers and analogies, sees an immutable and eternal order in the whole of the universe, intended, after the designs of the most perfect beneficence, to promote the happiness of millions of human beings, and where the whole of created nature offers its testimony to the existence of a Divine and Supreme intelligence.

I shall now conclude: Mr. Baily, you have been so good as to undertake to transmit the medal to Dr. Brinkley; no one is more capable of appreciating the high estimation in which his talents and character are held by the Royal Society. Assure him of our respect and admiration; inform him, that presiding, as he does over another kindred scientific body, we receive his communications not merely with pleasure but with gratitude, and that we trust he will continue them, both for the advancement of astronomy, and for the increase of his own high reputation.

DISCOURSE OF THE PRESIDENT,

Anniversary, Nov. 30th, 1825.

Character of Mr. William Higgins.—Award of two Copley Medals: one to M. Arago, F.R.S., M.R.A.S.P., for his Discovery of the Property possessed by Bodies in general to be affected by Magnetism; and the other to Mr. Peter Barlow, F.R.S., Professor at the Royal Military Academy at Woolwich, for his Discovery of a Method of Correcting the Errors of the Compass, arising from the Attraction of the Iron in a Ship.

I have, hitherto, in concluding this painful part of my duty, (announcing the deaths,) usually taken some particular notice of such of the deceased members, as have either contributed to your *Transactions*, or promoted, by their publications, the progress of science; or have encouraged the pursuit by their personal exertions and social interest, at our meetings; but upon this occasion I have scarcely more than the general sentiment of regret to offer. Many of the gentlemen whose names I have read to you were learned and ingenious men, and one of them a most laborious and industrious compiler*: but however their loss may be regretted by their friends, yet they can hardly be said to have been known sufficiently to the scientific world to call for particular notice before this body. I may except, perhaps, Mr. William Higgins, Professor of Chemistry to the Dublin Society, who published, nearly forty years ago, his *Comparative View of the Phlogistic and Antiphlogistic Theories*, which contains some ideas of

* Dr. Rees.

great importance with respect to what may be called the theory of definite proportions, or more commonly the atomic theory. He shows that bodies combine particle to particle, as 1 to 2 or 1 to 3, and so on; and he gives many very happy instances of such combination: but he brought forward no new experiments, and endeavoured to establish a loose kind of dynamic hypothesis. His work, however, contains many curious and ingenious views, and it is impossible not to regret that he did not establish principles which belong to the highest department of chemistry, and that he suffered so fertile and promising a field of science to be entirely cultivated by others; for though possessed of great means of improving chemistry, he did little or nothing during the last thirty years of his life.

COPLEY MEDALS.

It is now my duty to announce to you the decision of your Council with respect to the award of the Copleian medals.

The medal of this year's donation they have bestowed on M. Arago, Fellow of this Society, and Member of the Royal Academy of Sciences of Paris. And another medal, which was not disposed of on a former year, they have awarded to Mr. Peter Barlow, likewise a Fellow of this Society, and Professor in the Royal Military Academy at Woolwich.

The discoveries and labours which your Council have made it their pleasure and thought it their duty to honour, by conferring on their authors the highest rewards of this Society, belong to the same department of science—magnetism, a department which has always claimed a considerable portion of your attention,

both in its relation to philosophy and utility—to the laws and properties of natural bodies, and to navigation, the great source of the power and prosperity of this mighty empire.

That I may be able more distinctly to state the grounds of the decision of your council, I shall enter into a few historical details and general views on the subject, which I hope will not be unacceptable to our Fellows, not merely as setting forth the justice of the award, but as offering hopes of further discoveries, and as proving that though much has been done, more still remains to be effected for the distinct knowledge of the laws and relations of these mysterious phenomena.

That wonderful property by which a certain ore or stone attracted iron, seems to have been known from the most remote antiquity. The magnet was called by Aristotle, *κατ'εξοχην* "ἡ λιθος," and its name has been by some derived from the supposed discoverer, by others from the town or city in Asia where it was said to be discovered. Various Greek and Roman philosophers have described its attractive powers; and Pliny, amongst others, in his usually animated manner, in speaking of its attraction for iron, says, "Domitrixque illa rerum omnium materia ad inane nescio quid curret;" but its directive force, and consequently its use in navigation, was wholly unknown to the ancients.

We are uncertain when the polarity of the magnet was first applied to maritime purposes in Europe. The period is some time between 1100 and 1300.

By some of the ancient authors the discovery is referred to Flavio Gioia, a native of Amalfi, in the kingdom of Naples, in 1300; by others it is said to have been brought from the Indies, by Marco Polo, in 1240. The Chinese indeed pretend to have made the

discovery some ages before it was known to the Europeans; but the natural vanity of this people renders it impossible to depend upon any statement not connected with authentic historical documents.

That the compass did not point due north, (or its variation,) was discovered some time about the end of the 15th century, probably in the two great voyages to the eastern and western worlds, by Vasco de Gama and Christopher Columbus. The son of Columbus claimed the merit of this discovery for his father in 1495. By other writers, it is given to Sebastian Cabot, then in the employment of Henry VII. of England.

With respect to the change in the variation in the same place, and the knowledge of the dip of the needle, there is no such defect of historical precision; both the dates and the discoverers are well known. The dip was ascertained by Robert Norman, our countryman, in London in 1581, and the change of variation was accurately demonstrated by Professor Gellibrand of Gresham College, in 1635.

As the most important circumstances relating to the polar or directive force of magnetic bodies, were brought forward in this country, so likewise were the first just theoretical views respecting the circumstances of its communication and action. These views are owing to Dr. Gilbert of Colchester, who published his Latin treatise *De Magnete*, in 1600.

In this truly philosophical and original work, the author endeavours to prove that the phenomena of magnetism are owing to the magnetic polarity of the earth; that soft iron becomes a temporary magnet by the influence of the earth: that in steel the magnetic property is induced by the same cause with more difficulty, but that it is permanent; and he explains the motion of the

needle, and the power of common magnets, by showing that opposite poles of different magnets attract each other in some definite ratio of their distance. He indulges, which could hardly be avoided in that age, in some vague hypotheses, and details some futile experiments; but notwithstanding this, his views display very extraordinary powers of mind; and though censured by his contemporary Lord Bacon, for endeavouring to solve the phenomena of gravitation by magnetic attraction, yet his researches have a character of inductive reasoning, perfectly in the spirit of the philosophy of that great man, who, had he studied his work with more attention, would have found in it numerous examples of his own sublime method of pursuing science—a contempt for the speculative authority of the ancients, and an appeal, almost new in that time, to the laborious method of repeated experiments.

The general views of Gilbert were established, and his particular errors corrected by the early philosophers of this Society, by Wallis, Hooke, Halley, and Brooke Taylor.

The diurnal variation of the needle was discovered by George Graham, in 1722; and the same ingenious artist first applied the vibrations of the needle as a measure of magnetic intensity.

That magnetic attractions and repulsions follow the law of the square of the distance, has been regarded as nearly demonstrated by the experiments of Lambert, Coulomb, and Robinson; and mathematical views of the theory of magnetism, upon the hypothesis of a single magnetic fluid, have been brought forward by Epinus and Robinson; and the highest refinements and precision of the analytical method have been applied on the supposition of two fluids—the austral and the boreal,

in two very recent Memoirs of M. Poisson, presented to the Royal Academy of Sciences at Paris.

The hypothesis of magnetic, which so closely agrees with that of electric fluids, has been defended by similar arguments, and illustrated by analogous experiments; and the connexion between the two classes of phenomena had been often observed and dwelt upon by philosophers. Beccaria had, indeed, from the magnetic effects produced by lightning, endeavoured to solve the magnetism of the earth by supposing it produced by electrical currents, which were likewise the cause of the Aurora Borealis and Australis. But these, and other opinions of the same kind, were supported only by vague analogies and insufficient facts, and, till the discovery of M. Œrsted, the true relations of magnetism and electricity were unknown.

I could, with pleasure, dwell on this discovery, and the immediate consequences of it in the development of new and extraordinary results, and, would the time allotted to a discourse of this nature allow, I should have great satisfaction in describing to you the labours and the discoveries of various philosophers belonging to this and other learned Societies of Europe, and which have established, within the last five years, a perfectly new order of facts; not less brilliant from their striking and unexpected results, than important in their relations and theoretical applications to other phenomena of nature. I cannot, however, quit this part of my subject without calling your attention to the manner in which these discoveries have originated and been pursued, as it offers the most remarkable instance upon record of the unity of the laws of nature—of the manner in which remote phenomena are connected together, and the

happy consequence of due attention to unexpected or common results.

A fact, discovered by Galvani, and by him believed to be strictly physiological, investigated by the genius of Volta, was the origin of his wonderful pile or battery; and this instrument, after its powers had been apparently exhausted in demonstrating new laws in electricity, and affording us new creations in chemistry,—altering our arrangements and systems, became, in the hands of the Danish philosopher, a source of novel and unexpected combinations, throwing a light upon part of the corpuscular philosophy which were before in absolute darkness.

Though the labours of M. Arago, which have been the object of the vote of your Council, cannot be considered as immediate consequences of M. Œrsted's discovery, yet it is probable that they never would have been undertaken had not this discovery immediately excited the attention of their excellent author, who was amongst the first philosophers that endeavoured to investigate, compare, and illustrate the facts of electromagnetism.

Coulomb imagined that all substances in nature were susceptible of magnetic attractions; but from the nature of the bodies in which he supposed he had discovered these powers, it appeared probable that his results were owing to small quantities of iron in the material used.

When it was found that magnetism was always a consequence of electrical action, various experiments were made with hopes of producing magnetic effects in other metallic bodies besides those in which they have long been recognized; but it was found, with other metals, that all magnetic effect in electrical ex-

periments were transient, disappearing with the electrical cause.

Till M. Arago's inquiries, iron, nickel, and cobalt, and their combinations, were the only species of matter apparently affected by magnets. His experiments extend this property, under certain modifications, to all metallic substances, and it is said, though we have as yet no distinct details, to water, and various other bodies.

M. Arago found that the extent of the vibrations of a magnetized needle, or the spaces through which it moved, were greatly diminished by holding over it a plate of copper; and by causing a plate of copper to revolve below it, the direction of the needle was soon changed; it began to turn round, and the velocity of its revolutions increased, till at last they became so quick as to be incapable of being numbered. M. Arago made the same trials with other metallic substances and with similar results, differing, as might be expected, in intensity; and his experiments have been successfully repeated by Messrs. Herschel and Babbage, and by Mr. Christie of Woolwich. Messrs. Herschel and Babbage have not only confirmed, but extended and illustrated them by new inquiries. As action and re-action must in all cases be equal, it occurred to them to set in motion metallic plates by magnets, and they have been perfectly successful. A powerful horse-shoe magnet, made to revolve beneath metallic plates, sets them in motion, and gives them a great velocity of revolution. In these experiments, which I have had the satisfaction of witnessing, not only zinc, lead, tin, bismuth, and antimony have been used, but likewise mercury and carbon, in that state in which it is found in the retorts at gas manufactories, and with similar

results, though differing considerably in degree. MM. Herschel and Babbage, in a paper printed in the last part of the *Transactions*, have developed their researches and views in a very masterly manner; and those who wish to enter into this new field of science, cannot do better than study their experiments and their reasoning.

It is for the discovery of this fact,—the power of various bodies, principally metallic, to receive magnetic impressions, in the same, though in a more evanescent manner than malleable iron, and in an infinitely less intense degree,—that your Council have awarded your medal; and you, I am sure, cannot but approve of their decision, for whether in its immediate relations or ultimate applications, there is no physical fact which has been made known, during the present year, that can, with propriety, be put in competition with it.

By extending the empire of magnetism to a number of bodies, it removes much of what was mysterious and inexplicable in that department of science, and renders it a branch of the general philosophy of nature; and when the new analogies between magnetic and electrical action, established by these phenomena, are considered, there is much reason to hope that they may be ultimately referred to the same cause with chemical affinity, and possibly be found identical with the general quality or power of attraction of gravitation.

Mr. Barlow has published several papers in the *Transactions of the Royal Society*, which have established his character, both as a judicious and accurate experimenter and able reasoner. These papers are,—1. On the Effects produced on the Rates of Chronometers by the Proximity of Masses of Iron.—2. On the Diurnal

Variations of Magnetized Needles under a reduced Directive Power.— 3. On the Anomalous Magnetic Action of Ignited Iron at different Temperatures.— 4. On the temporary Magnetic Effects produced in Iron by its Rotation. And he has likewise given to the world a treatise, in which he has endeavoured to explain the phenomena of magnetism by mathematical principles, according to an hypothesis, the same in its ground-work as that of the French philosophers, and in which the circumstances of the connection of magnetic powers with surface is demonstrated, and the whole subject treated with great ability and profound knowledge.

The curious facts brought forward by Mr. Barlow, and the general accuracy of his reasoning, and the spirit of induction in his researches, would undoubtedly have claimed the attention of your Council, and might have led them to balance his merits with those of other contributors to your *Transactions*; but their opinion was fixed, and their decision formed by a practical application of science, of great ingenuity and considerable utility.

All persons, who have attended at all to the phenomena of magnetism since the time of Gilbert, know that masses of iron become magnetic by the action of the earth; a bar of soft iron, for instance, held vertically, has its north pole uppermost, and attracts the needle in the same manner as the pole of the earth; and any quantities or masses of iron, following the same law, exert an action on the needle proportional to the square of the distance, and of course destroy or diminish, in a certain ratio, the action of the north pole of the earth. It is extraordinary that so important a circumstance as the action of the iron in a ship on the

needle, had not earlier and more strongly arrested the attention of navigators. Even Dr. Halley, the most accomplished and profound philosopher that ever made long voyages, though he observed the effect, does not seem to have thought it worthy of correction, and that, when making a set of minute observations on variations, he says, in his paper in the *Transactions*, "We know by experience how little the iron guns on board a ship affect the needle." This, however, probably arose from the circumstances, that he was never in very high latitudes. Mr. Wales, the astronomer in Captain Cook's voyage, seems to have observed the fact, but Walker, in his *Treatise on Magnetism*, was the first person who called the attention of nautical men to the circumstance. Captain Flinders brought it before the notice of the Admiralty, and Mr. Bain pointed out the fatal consequences attending it as a source of error in reckoning; and lately the Arctic Expeditions have given the fairest and fullest opportunity of determining the circumstance, as may be learnt in the narrations of Captains Ross, Sabine, Parry, Lyon, and other able officers; and some correct general views on the subject have been brought forward by M. Lecount.

Mr. Barlow, after making a number of experiments on the phenomena presented by different large masses of iron, and recurring to the principle, that the contiguity of a small mass, makes it equal or superior in power to larger masses, and that the attractions and repulsions diminish as the square of the distance, thought of two methods of correcting the errors arising from the magnetism of the iron in ships; one by compensating, the other by doubling them, by means of small masses, or thin plates of iron, placed near the compass, and the relation of which to the magnetism of

the earth, the iron in the ship, and the needle, should be determined by experiments.

The last method he has adopted in practice; and though, as M. Poisson has shown, it cannot be considered strictly and mathematically precise, yet it may be regarded as sufficiently exact for all common purposes of navigation, and its utility has already been proved by the observations of Captain Baldey, Captain Sabine, Captain Parry, Lieutenant Mudge, Lieutenant Foster, and various other able and enlightened officers.

The Royal Society has always, since its first establishment, given particular encouragement, and particular attention, to those departments of science which are strictly practical, and which offer the best vindication and the highest praise of the experimental and inductive method, bringing philosophy, as it were, from the heavens to the earth, and fixing her abode, not in visionary, splendid, and airy edifices, but amongst the resting-places and habitations of man. To point out a useful application of any doctrine or discovery, has always been their highest pride, and fortunately they have had many noble opportunities and examples; indeed, there is scarcely any instance of a considerable advance made in the knowledge of nature, without being soon connected with some tangible benefit or advantage, as light is almost always accompanied by heat, the illuminating by the productive and nourishing principle.

In conformity to the usages and feelings of the Society, the Council has awarded the medal to Mr. Barlow, who, by reasoning and experimenting upon a few simple facts, long known, but never applied, has founded a useful invention, tending to the perfection of an in-

strument, the most important, perhaps, to Britons, of all those which have been the result of scientific principles, increasing the perfection of an art, which is not only one of the greatest sources of our power, but a bond of union amongst nations, securing their intercourse, and extending the progress of commerce, civilization, and refinement.

Mr. South,

In transmitting this medal to M. Arago, assure him of the interest we take in his ingenious and important researches; and inform him that we wait with impatience for the continuation of his labours on this new and fertile subject. As one of our Fellows, his discoveries have the same interest for us, that they have for his brethren of the Royal Academy of Sciences, which, for more than a century and a half, has gone on encouraging and emulating our labours. You and our worthy secretary* are recent examples of liberality on their part, and of the respect paid to British talent; we, I trust, shall never be behind them in dignity and nobleness of sentiment: far be from us that narrow policy which would contract the minds of individuals, and injure the interest of nations, by cold and exclusive selfishness; which would raise the greatness of one people, by lowering the standard of that of another. As in commerce, so in science; no country can become worthily pre-eminent, except in profiting by the wants, resources, and wealth of its neighbours. Every new discovery may be considered as a new species of manufacture, awaking novel industry and sagacity, and employing, as it were, new capital of mind. When Newton developed the system of the universe, and established

* Mr. Herschel.

his own glory and that of his country on imperishable foundations, he might be regarded as giving a boon to the civilized world, for which no adequate compensation could ever be made; yet, even in this, the most difficult and sublime field of discovery, Britain has been paid, if not fully, yet fairly, by the labours of Euler, La Grange, and, above all, Laplace; perfecting the theory of the lunar motions and planetary perturbations, and affording data of infinite importance in the theory and practice of navigation. Fortunately science, like that nature to which it belongs, is neither limited by time nor by space. It belongs to the world, and is of no country and no age. The more we know, the more we feel our ignorance; the more we feel how much remains unknown; and in philosophy, the sentiment of the Macedonian hero can never apply,—there are always new worlds to conquer.

Mr. Barlow,

I have great pleasure in presenting you with this medal, in the name of the Royal Society. Receive it as the highest mark of distinction which they have it in their power to bestow. You have already received marks of approbation, both at home and abroad, far more valuable in a pecuniary point of view, but no one which I think ought to give you more durable satisfaction; for this reward has, I believe, never been made, except after dispassionate and candid discussion; never to gratify private feelings, or to call for popular applause; and, amongst the philosophers who have received it, are names of the very highest rank in science. We trust, both on account of the public good, and your own glory, that you will engage in, and accomplish,

many new labours; you have had not merely scientific success, but one still more gratifying to your heart and feelings, the idea that you have been useful to your country, and secured the gratitude of a body of men who are not tardy in acknowledging benefits.

DISCOURSE OF THE PRESIDENT,

ANNIVERSARY, 1826.

Characters of TAYLOR COMBE, Esq., and Sir THOMAS STAMFORD RAFFLES.—Award of the Royal Medals to Mr. JOHN DALTON, F.R.S., for his Development of the Theory of Definite Proportions, usually called the Atomic Theory of Chemistry; and to JAMES IVORY, Esq., F.R.S., for his various Mathematical Papers, published in the Philosophical Transactions. And on the Award of the COPLEY Medal to JAMES SOUTH, Esq., F.R.S., for his Observations on Double Stars.—With General Views on the Scientific History and Particular Merits of the Subjects for which the Prizes were given.

I CANNOT pass over two of the names in this list without an expression of sorrow, at the loss the Society and the public have sustained in their death. Taylor Combe, Esquire, for many years one of your secretaries, was distinguished as a learned antiquarian, an elegant and accomplished classical scholar, and an excellent judge of works of art. In his official situation in your service, he attended with great care and accuracy to the publication of the *Transactions*, till the state of his health interfered with his business and pursuits. In his public situation in the British Museum, he was most easy of access, and accommodating in promoting the pursuits of artists and scholars. His loss will be severely felt in the sister Society of Antiquarians, and lamented by all who were acquainted with the genuine worth of his character, the good nature and candour of his mind, and the kindness and simplicity of his manners.

Sir T. Stamford Raffles was not a contributor to your *Transactions* directly; yet he was the occasion of many discoveries in zoology, botany, and physiology. His disinterested promotion of every branch of natural history; his sacrifice of his fortune and his time to collections in this department of knowledge; the readiness with which he laid them open to scientific men, claimed the highest admiration. Occupying high situations in our Empire in the East, he employed his talents and his extensive researches, not in the exercise of power or the accumulation of wealth, but in endeavouring to benefit and to improve the condition of the natives, to found liberal institutions, and to establish a permanent commercial intercourse between the colonies where he presided, and the mother country, which, whilst it brought new treasures to Europe, tended to civilize and to improve the condition of the inhabitants of some of the most important islands of the East. Neither misfortune nor pecuniary losses damped the ardour of his mind in the pursuit of knowledge. Having lost one splendid collection by fire, he instantly commenced the formation of another: and having brought this to Europe, he made it not private, but public property, and placed it entirely at the disposition of a new Association,* for the promotion of zoology, of which he had been chosen President by acclamation. Many of the Fellows of this Society can bear testimony to his enlightened understanding, acute judgment, and accurate and multifarious information; and all of them must, I am sure, regret the premature

* [The Zoological Society: of this association the author was one of the warmest promoters; he was concerned in forming the plan on which it was established, and the first address to the public, announcing it and soliciting support for it, was from his pen.]

loss of a man who had done so much, and from whom so much more was to be expected, and who was so truly estimable in all the relations of life.

On our foreign lists of deaths, there is only one name.

Padre Joseph Piazzi, formerly of Palermo, and late of Naples, whose name will descend to posterity, connected with one of the most important discoveries of the age, that of the planet Ceres; and who, for nearly half a century, had pursued his favourite science with great ardour and success. He died, according to the course of nature, in old age, having enjoyed a glory, which in no respect disturbed his repose.

ROYAL MEDALS.

You will recollect, Gentlemen, that the Right Honourable the Secretary of State for the Home Department,* who, I am happy to state, has, upon all occasions, shown his zeal to promote the interests of science, and of the Royal Society, announced at your Anniversary dinner, last year, his Majesty's gracious intention of founding two annual prizes, each of the value of fifty guineas, to be at the disposal of the President and Council of the Royal Society, for promoting the objects and progress of science, by awakening honourable competition amongst philosophers.

As this foundation was announced in the true spirit of royal munificence, so it has been completed with an exalted liberality, worthy of our august patron. The two prizes are established in the forms of silver and gold medals, to be given for important discoveries or useful labours in any department of science; and they

* [Sir Robert Peel.]

are laid open to learned and ingenious men of all countries, without any principle of narrow policy or national exclusion.

In the first award of these royal medals, your Council have had some difficulties in their decision. Discoveries are sometimes made of great interest, which require time and new labours for their confirmation; and when their importance is great and their bearings extensive, years even may pass away, before a full conviction of their truth can be obtained. Now, though within the year just past, there have been more than one important discovery announced to the world, yet there are none which can be said to be, as yet, fairly and securely established.

Your Council, therefore, have rather looked to labours which have been sanctioned by time, the importance of which is generally felt, though not sufficiently acknowledged; which may be said to have acquired their full authority only within a very short period, and which, consequently, may be considered as within the literal meaning of the foundation.

I trust you will approve of the principle of the decision, and of the manner in which it has been made by your Council.

They have awarded the first prize to Mr. John Dalton, of Manchester, Fellow of this Society, for the Developement of the Chemical Theory of Definite Proportions, usually called the Atomic Theory, and for his various other labours and discoveries in physical and chemical science.

What Mr. Dalton's merits are, I shall briefly endeavour to state to you, though it is impossible to do justice to them, in the time necessarily allotted to this address.

The brilliant and important discoveries of Black, Cavendish, Priestley, and Scheele, had added to chemistry a great variety of substances before unknown, many of which had forms never before witnessed in the material world; and the new and accurate logic of Lavoisier had assigned to many of them their just places in the arrangements of chemistry, and had established the characters of most of them, as simple or compound bodies. Novel uses of these substances were ascertained, new combinations of them made, and their applications to the purposes of common life, constantly extended by various distinguished chemists, in the close of the last century; but with respect to the weight or quantity in which the different elementary substances entered into union to form compounds, there were scarcely any distinct or accurate data. Persons, whose names had high authority, differed considerably in their statements of results, and statical chemistry, as it was taught in 1799, was obscure, vague, and indefinite, not meriting even the name of a science.

To Mr. Dalton belongs the distinction of first unequivocally calling the attention of philosophers to this important subject. Finding, that in certain compounds of gaseous bodies the same elements always combined in the same proportion; and that when there was more than one combination, the quantity of the elements always had a constant relation, such as 1 to 2, or 1 to 3 or to 4. He explained this fact, on the Newtonian doctrine of indivisible atoms, and contended that the relative weight of one atom to that of any other atom being known, its proportions or weight, in all its combinations, might be ascertained; thus making the statics of chemistry depend upon simple questions, in subtraction or multiplication, and enabling the student to de-

duce an immense number of facts, from a few well authenticated, accurate, experimental results.

I have said that to Mr. Dalton belongs the distinction of first unequivocally calling the attention of philosophers to this subject; but I should be guilty of historical injustice, if I did not state that various opinions and loose notions on the same mode of viewing the combinations of bodies, had existed before. And not to go back to the time of the Greek schools, to the Homoids of Anaxagoras, or to the Atoms of Epicurus, nor to those Newtonian philosophers who supported the permanency of atoms, and their uniform combinations, such as Keil, Freind, Hartley, and Marzucchi; there may be found in the works of Dr. Bryan Higgins, Mr. William Higgins, and Professor Richter, hints or conclusions, bearing decidedly on this doctrine. Dr. Bryan Higgins, in his Experiments and Observations, relating to acetous acid, fixable air, dense, inflammable air, fire, and light, published in 1786, contends that elastic fluids unite with each other in limited proportions only; and that this depends upon the combination of their particles or atoms, with the matter of fire which surrounds them as an atmosphere, and makes them repulsive of each other; and he distinguishes between simple elastic fluids, as composed of particles of the same kind, and compound elastic fluids, as consisting of two or more particles combined, in what he calls molecules, definite in quantity themselves, and surrounded by definite proportions of heat. Dr. Bryan Higgins' notions have, I believe, never been referred to by any of the writers on the Atomic Theory. Mr. William Higgins' claims have, on the contrary, often been brought forward. Yet, when it is recollected, that this gentleman was a pupil and relation of Dr. Bryan Higgins, and that his work, called

the *Comparative View*, was published some years after the treatises I have just quoted, and that his notions are almost identical (with the addition of this circumstance, that he mentions certain elastic fluids, such as the compounds of azote, consisting of 1, 2, 3, 4, and 5 particles of oxygen to one of azote,) it is difficult not to allow the merits of prior conception, as well as of very ingenious illustration, to the elder writer.

Neither of the Higgins attempted to express the quantities in which bodies combine by numbers; but Richter has a claim of this kind. In his *New Foundations of Chemistry*, published in 1795, he has shown that when neutro-saline bodies in general undergo mutual decompositions, there is no excess of alkali, earth, or acid; and he concludes that these bodies are invariable in their relation to quantity, and that they may be expressed by numbers.

Mr. Dalton, as far as can be ascertained, was not acquainted with any of these publications, at least he never refers to them: and whoever will consider the ingenious and independent turn of his mind, and the original tone prevailing in all his views and speculations, will hardly accuse him of wilful plagiarism. But let the merit of discovery be bestowed wherever it is due; and Mr. Dalton will be still pre-eminent in the history of the theory of definite proportions. He first laid down, clearly and numerically, the doctrine of multiples; and endeavoured to express, by simple numbers, the weights of the bodies believed to be elementary. His first views, from their boldness and peculiarity, met with but little attention; but they were discussed and supported by Drs. Thomson and Wollaston; and the table of chemical equivalents of this last gentleman, separates the practical part of the doctrine from the atomic or hypo-

thetical part, and is worthy of the profound views and philosophical acumen and accuracy of the celebrated author.

Gay Lussac, Berzelius, Dr. Prout, and other chemists, have added to the evidence in favour of the essential part of Mr. Dalton's doctrine; and for the last ten years it has acquired almost every month additional weight and solidity.

Gentlemen, I hope you will clearly understand that I am speaking of the fundamental principle, and not of the details, as they are found in Mr. Dalton's system of chemical philosophy. In many of these, the opinion of the composition of bodies is erroneous, and the numbers gained from first and rude experiments, incorrect; and they are given with much more precision in later authors on chemistry. It is in the nature of physical science, that its methods offer only approximations to truth; and the first and most glorious inventors are often left behind by very inferior minds, in the minutiæ of manipulation; and their errors enable others to discover truth.

Mr. Dalton's permanent reputation will rest upon his having discovered a simple principle, universally applicable to the facts of chemistry—in fixing the proportions in which bodies combine, and thus laying the foundation for future labours, respecting the sublime and transcendental parts of the science of corpuscular motion. His merits, in this respect, resemble those of Kepler in astronomy. The causes of chemical change are as yet unknown, and the laws by which they are governed; but in their connexion with electrical and magnetic phenomena, there is a gleam of light pointing to a new dawn in science; and may we not hope that, in another century, chemistry having, as it were, passed

under the dominion of the mathematical sciences, may find some happy genius, similar in intellectual powers to the highest and immortal ornament of this Society, capable of unfolding its wonderful and mysterious laws.

I could with pleasure enter into a history of Mr. Dalton's other labours in chemical and physical science, but it would be impossible to give even an intelligible sketch of them, without occupying too much of the time which ought to be allotted to the other business of this day. His experiments, on the equal expansion of elastic fluids by heat, are allowed to be accurate, and their results well founded. His notions on the nature of the atmosphere, the mixture of gaseous bodies, and the distribution and communication of heat, and on the magnetic phenomena, display the resources of an ingenious and original mind; and his essays on evaporation, and the force of vapour, and the tests for discovering water in air, have offered important practical applications; but still their interest, though of a high kind, is inferior to that of the doctrine of definite proportions.

I trust you will allow the justice of the decision of your Council, which has claimed for our countryman this first testimony of royal benevolence to science.*

There is another motive which influenced them, and which I am sure will command your sympathy. Mr. Dalton has been labouring, for more than a quarter of a century, with the most disinterested views. With the greatest modesty and simplicity of character, he has remained in the obscurity of the country, neither asking for approbation, nor offering himself as an object of ap-

* [By a writer of some note this decision of the Council of the Royal Society in awarding the first royal medal to Mr. Dalton, has been called, by some unaccountable perversity of understanding, an insult to this distinguished man.]

plause. He is but lately become a Fellow of this Society; and the only communication he has given to you is one, compared with his other works, of comparatively small interest; their feeling on the subject, is therefore pure. I am sure he will be gratified by this mark of your approbation of his long and painful labours. It will give a lustre to his character, which it fully deserves; it will anticipate that opinion which posterity must form of his discoveries; and it may make his example more exciting to others, in their search after useful knowledge and true glory.

Your Council have awarded the second binary medal on the royal foundation, to James Ivory, M.A., for his papers on the Laws regulating the Forms of the Planets, on Astronomical Refractions, and on other Mathematical Illustrations of important Parts of Astronomy.

Every one who considers the glory derived to the Royal Society and to this nation, by the invention of the fluxional or differential calculus, and its application to the laws of the system of the universe, — every one who remembers the ascendency which for more than fifty years this Society enjoyed in the most sublime department of science, and the honour that would result from recovering it, will, I am sure, be pleased with this decision of your Council, the object of which is, not only to reward a highly distinguished individual, but likewise by setting forth his example, if possible to encourage others to pursue the same honourable career.

All Mr. Ivory's most important mathematical labours have been communicated to the Royal Society, and published in your *Transactions*.

These communications are seven in number. Five,

including the first paper given in to the Society, in 1809, and the last published in 1825, are on the Forms which Spheroidal Bodies must assume, revolving on their Axes, and acted on by the known Laws of Gravity and the Centrifugal Force. Of the two others — one is on a new Method of deducing the Approximation to the Orbit of a Comet, and the other of the Astronomical Refractions.

One of the most important problems which exercised the skill of the illustrious author of the *Principia*, was the effect of gravity and the centrifugal force in giving a peculiar form to a fluid mass; which he calculated would correspond to the figures of the earth and the other planets. Maclaurin elucidated Newton's idea by a very refined and elegant synthetical process of reasoning. He determined generally the attractive forces of a homogeneous spheroid of revolution on a point placed within the solid or in its surface; but there were still difficulties left, when the attracted point is placed without the solid, which were solved by the ingenuity of Legendre. The Marquis de la Place, in his *Mechanique Celeste*, took a more enlarged view of the problem, and extended his method to all elliptical spheroids; but notwithstanding the refined principles and profound investigations of this illustrious geometer, and the elucidations of them attempted by his friend and rival La Grange, there were some points unsolved, remaining in the application of the formulæ and the generalization of the theorems, which awakened Mr. Ivory's attention, and which led him to examine the whole subject anew. In his first paper he considers the ellipsoid as homogeneous, and treats the problem by the method of three co-ordinates. In his second and third papers he examines with great minuteness the

methods of M. de la Place, and M. de la Grange. In his fourth paper he extends his own method to all such spheroids as have their radii expressed by rational and integral fractions of three rectangular co-ordinates of a point in the surface of a sphere. And in the fifth he solves the problem in its generality, considering the body as a fluid homogeneous ellipsoid of revolution. I cannot pretend to give any idea of the mathematical resources displayed in these problems, and which even the most accomplished geometer could not render intelligible by words alone; but I can speak of the testimony given by M. de la Place himself in their favour. That illustrious person, in a conversation which I had with him some time ago, on Mr. Ivory's first four communications, spoke in the highest terms of the manner in which he had treated his subject; one he said of the greatest delicacy and difficulty, requiring no ordinary share of profound mathematical knowledge, and no common degree of industry and sagacity in the application of it.

Comets, before the foundation of this Society, were considered rather as objects of superstitious awe and vulgar astonishment, to be feared as portents, or admired as wonders, than regarded as celestial phenomena, having a regular place and order in the solar system. The uncertainty of their appearances, their changes in brightness, the alterations in their most remarkable feature, the coma or tail, the rapidity and irregularity of their motions, sometimes nearly rectilineal, sometimes greatly curved, and sometimes retrograde, prevented even the most distinguished early astronomers, including Kepler, from forming any just opinions respecting their nature or their motions: and it was reserved for the unrivalled sagacity of Newton to show that they

belonged to the same system, and were governed by the same laws as the planetary bodies, moving like them in conic sections but in different curves, depending upon the proportion of rectilineal velocity to the quantity of deflection by gravitation towards the sun.

The triumph of the Newtonian views of the cometary system was considered as completed by the return of the comet predicted by Halley in 1759; but still great difficulties existed in laying down any general methods for calculating their times of return and places—from the circumstance of the earth and comet being both in motion—from the uncertain nature of the curve, and the disturbing causes which may act unknown to the observer, in space. Such celebrated men as Boscovich, Legendre, Lambert, La Place, and Gauss, have all contended with these difficulties with a success more or less partial. Notwithstanding the authority of such names, Mr. Ivory has not feared to enter into the same field of investigation, and he conceives that, considering the orbit of a comet as parabolic, three geocentric observations of its place are sufficient to furnish, by the method which he has proposed, elements for determining its course nearer the true ones, than they have been generally supposed, and a good first approximation to the solution of a problem, which in some of its conditions must be indeterminate.

I shall say a few words only of Mr. Ivory's paper on the Astronomical Refractions.

The ancient astronomers had observed that there was a difference between the real and apparent places of the stars, arising from the refraction of light in passing through the atmosphere. Tyche Brahè by rude methods sought to free his observations from the effect of this irregularity; and the problem has occupied the at-

tention of Cassini, Kramp, La Place, Bessel, and Brinkley.

A ray of light from a star, in passing through the atmosphere to the surface of the earth, is bent from its rectilineal course, by an attraction which depends principally on the density of the air, resulting from pressure and temperature.

If the atmosphere had consisted only of a single elastic fluid, the temperature and pressure of which diminished according to a regular and uniform ratio from the surface of the earth, the problem of refractions would be an exceedingly simple one; but unfortunately there are many causes which as yet are only imperfectly understood, that make the conditions much more complicated—the radiation of heat from the earth, the deposition of water, and the uncertainty whether the upper regions of the atmosphere are similar in composition to the lower ones.

Mr. Ivory's investigation is a very refined one. He has considered most of the uncertainties and all the difficulties of the subject; and if it is still left in an unfinished state, in making the corrections for stars near the horizon, it is not owing to any want of mathematical skill or acuteness of logic in this profound author; but to the imperfection of our physical experiments which must furnish the data in all operations of this kind.

Whoever considers the fluctuations of the barometer, thermometer, and hygrometer in this climate at this season, and the different effects of radiation or cooling causes in the nights, will have an idea of the difficulty of the subject, and the impossibility, it may be so called, with the present tables of determining the true place of a star, within the limits of these changes.

Your Council of this year, as you know, Gentlemen, contains several distinguished mathematicians, who were decisive in claiming this award for Mr. Ivory, and I trust your approbation will sanction their decision. I may likewise apply to Mr. Ivory praise of the same kind as that which I had the honour of applying to Mr. Dalton. He has pursued science with the same disinterested zeal, and as it were, with a pure affection for the cause of truth. He has received no emoluments, and occupied no places of dignity. He has quietly and unobtrusively brought forward his labours—they have had no popular object, and only a high scientific aim; being intelligible only to a few superior minds, and he has waited for the slow progress of time to ensure him their confidence and approbation.

I feel the highest satisfaction in anticipating that this award may renovate the activity of the Society upon this department of science, and that it will return, "veteris vestigia flammæ," with new ardour to its so long-neglected fields of glory.

Whether we consider the nature of mathematical science or its results, it appears equally amongst the noblest objects of human pursuit and ambition. Arising a work of intellectual creation, from a few self-evident propositions on the nature of magnitudes and numbers, it is gradually formed into an instrument of pure reason of the most refined kind, applying to and illustrating all the phenomena of nature and art, and embracing the whole system of the visible universe: and the same calculus measures and points out the application of labour, whether by animals or machines—determines the force of vapour, and confines the power of the most explosive agents in the steam engine—regulates the forms of structures best fitted to move through the

waves — ascertains the strength of the chain-bridge necessary to pass across arms of the ocean—fixes the principles of permanent foundations in the most rapid torrents—and leaving the earth filled with monuments of its power, ascends to the stars, measures and weighs the sun and the planets, and determines the laws of their motions, and even brings under its dominion those cometary masses that are, as it were, strangers to us wanderers in the immensity of space; and applies data gained from the contemplation of the sidereal heavens to measure and establish time and movement, and magnitudes below.

COPLEY MEDAL.

There is another annual medal, Gentlemen, on which I have to announce to you the decision of your Council, that founded on the donation of Sir Godfrey Copley, Bart. This, for a long while, was the only mark of distinction which you had to bestow: and when the illustrious names to whom it has done honour are considered, and the great and extraordinary advances in natural knowledge with which the award has been connected, it will, I trust, continue to retain all its dignity, as a mark of our respect, and all its importance as a pure honorary reward. It has been voted this year to James South, Esq., Fellow of the Royal Society, for his paper of Observations of the Apparent Distances and Positions of four hundred and fifty-eight double and triple Stars, published in the present volume of the *Transactions.*

The illustrious Florentine philosopher to whom we owe the discovery of the telescope, and all the *first* pure experimental results in natural philosophy, was, as I

mentioned in a former discourse, the author of the idea of attempting the discovery of the parallax of the fixed stars by the observation of double stars. Galileo supposing the fixed stars to be analogous to our sun in nature and magnitude, but at immense distances from us, and from each other, proposed the observation of two stars of different apparent sizes, and seemingly very near each other, at the summer and winter solstice, giving the two extremities of the earth's orbit, with the hope that a difference might be observed in their position, indicating parallax.

This method was insisted on by Dr. Wallis, but not put in practice, as the questions respecting the discoveries of Newton soon occupied, almost exclusively, the attention of philosophers.

Dr. Bradley and Mr. Molyneux, in endeavouring to follow the observations of Hooke to determine the parallax of fixed stars near the zenith, by an instrument constructed by Mr. George Graham, and more accurate than had ever before been made, believed they observed a proper and considerable motion of γ Draconis: and Dr. Bradley, after Mr. Molyneux's death, pursuing the same inquiries from 1727 to 1748, was convinced of an apparent motion of this, and of other fixed stars.

The Rev. Mr. Michell, in a very ingenious and elaborate paper published in the *Philosophical Transactions* for 1767, developes some new and very ingenious views of the sidereal system. He supposes that stars may be arranged in groups; and to whatever cause this may be owing, whether to their mutual gravitation, or to some other law or appointment of the Creator, he supposes that some of them may act to others the parts of secondary to primary planets, or of planets to the sun.

Fortunately for astronomy Sir William Herschel took

up this subject in 1779, principally with the hope of discovering parallax; but though he failed in this object, yet his observations led to new and most important discoveries, confirming and extending the ideas of Mr. Michell, and advancing, in a most extraordinary manner, our knowledge of the system of the universe.

The results of Sir William Herschel's observations from 1779 to 1784, were published in two catalogues in the *Philosophical Transactions* for 1782 and 1785, and consist of descriptions and measures of seven hundred and two double and triple stars. The labour of re-examination was undertaken and executed by him in 1801, 1802, 1803, and 1804, after a lapse of twenty years, and the changes observed or suspected, were recorded in two other papers published in the volumes of the Society for 1802 and 1804. In 1816 a second examination of the measures was commenced by Mr. Herschel, a son worthy of his father, and some progress made in it; and Mr. South being in possession of certain instruments, perfected by the labour and skill of Mr. Troughton, became associated with Mr. Herschel in these researches, which were recommenced in March, 1821, and carried on by Mr. Herschel and Mr. South jointly till 1824, and their results published in an extensive memoir, containing their observations of three hundred and eighty double or triple stars in the *Transactions* of that year.

By these observations many of the conclusions and suspicions of Sir William Herschel were proved, the existence of binary systems in which two stars appear to perform to each other the office of sun and planet was distinctly shown, and the periods of rotation of more than one such pair determined in a manner approaching to exactness; the immersions and emersions

of stars behind each other were demonstrated, and real motions amongst them detected, rapid enough to become sensible and measurable in very short intervals of time.

These important researches were continued by Mr. South, at Blackman Street, and at Passy, near Paris, in 1823, 1824, and 1825, and their results form the first part of the *Philosophical Transactions* for this year. The work which, as I have already mentioned, is the object of the award of your Council.

These laborious and accurate observations, which fill three hundred and ninety-one pages, relate to four hundred and fifty-eight double and triple stars: of these one hundred and twenty-three were discovered and observed by Sir William Herschel, one hundred and sixty were discovered by Mr. South, at Passy, and the remaining one hundred and seventy-five by other astronomers.

There are some very curious, I may say almost wonderful, instances of proper motions of stars, of occultations of stars by each other, proved in these pages; but the most important result is, the apparent connexion of stars in binary systems of rotation, which seems to render it probable that the law of gravitation extends to this part of the universe. There are forty-three phenomena of this kind observed by Mr. South: in some the matter is placed he thinks beyond all possibility of doubt; whilst in others, the motion being less rapid, observations at a future and more distant period are required to establish the fact with security.

As amongst the most interesting of the double stars, we may enumerate the following:—ϵ Bootis, γ Virginis, α Geminorum, (or Castor), σ Coronæ Borealis,

η Cassiopeiæ, 61 Cygni, ξ Ursæ Majoris, and 70 Ophiuchi.

ε *Bootis.*—Large white, small blue; distance, 3 seconds and 4-tenths; period, about 822 years—motion direct.*

γ *Virginis.*—8th and 8½ magnitudes; both white; distance, 3 seconds and 3-tenths; period, about 540 years—motion retrograde.†

α *Geminorum* (*or Castor*).—3rd and 4th magnitudes; both white; distance, 4 seconds and 8-tenths; period, about 373 years—motion retrograde.

σ *Coronæ Borealis.*—6th and 8th magnitudes; distance, 1 second and 5-tenths; period, about 169 years—motion direct.

η *Cassiopeiæ.*—6th and 9th magnitudes; large red, small green; distance, 9 seconds and 9-tenths; period, about 700 years—motion direct.

61 *Cygni.*—7th and 8th magnitudes; both white; distance, 15 seconds and 4-tenths; period, about 493 years—motion direct.

ξ *Ursæ Majoris.*—6½ and 7th magnitudes; both white; distance, 2 seconds and 4-tenths; period, about 71 years—motion retrograde.

70 *Ophiuchi.*—8th and 8½ magnitudes; distance, 4 se-

* nf. sp. † np. sf.

conds and 8-tenths; period, about 53 years—motion direct.

TRIPLE STARS.

12 *Lyncis.*—A of the 7th, B of the 7½, and C of the 9th magnitudes; of AB, distance, 2 seconds and 5-tenths; of AC, 9 seconds and 2-tenths; period of AB (or the close pair) 646 years—motion retrograde; whilst AC (or the distant pair) have not materially changed.

ξ *Scorpii.*—A of the 7th, B of the 7th, and C of the 9th magnitudes; of AB, distance, 1 second and 4-tenths; of AC, 7 seconds.

The close pair, AB, has suffered no alteration since it was observed by Sir William Herschel, in 1782.

Whereas the period of the distant pair, or AC is probably about 1406 years—motion retrograde.

Two instances are furnished in which occultations of stars by others have occurred; they are δ Cygni, and ζ Herculis; and this fact is confirmed by the inquiries of Professor Struve, at Dorpat; and some additional confirmations of the proper motions of other stars have been recently made by Dr. Brinkley, now Bishop of Cloyne, at Dublin.

When the importance of an acquaintance with the position of the fixed stars in the heavens is considered, on the accurate knowledge of which all our data in refined astronomy, and many of those in practical navigation, depend: and when the new and sublime views of the arrangements of infinite wisdom in the starry heavens, resulting from these inquiries, are considered, you will, I am sure, approve of this vote of your Council.

Mr. Herschel has, on another occasion, enjoyed the

honour of the Copley medal: and a like mark of your respect is surely due to his fellow-labourer, who, having provided his own instruments, at a great expense, has employed them at home, and carried them abroad, trusting entirely to his own resources, and pursuing his favourite science in the most disinterested and liberal manner, communicating all his results to this Society.

There is a reason, likewise, which must be almost considered as personal. Whoever has seen the methods in which observations of this kind are conducted, must be aware of the extreme fatigue connected with them, of the watchful and sleepless nights that must be devoted to them, of the delicacy of manipulation they require, and of the sacrifices of ease and comfort they demand!

In dwelling upon this award, there is another circumstance to which I cannot but allude; it fixes, as it were, the perfection and delicacy of the instruments employed, without which all labour would be in vain. In these instances of research, man, as it were, conquers space, and triumphs over time; and by almost infinitely minute and delicate resources, by aids which may be called microscopic, contemplates and embraces the grandest objects: and if the pure, mathematical sciences obtain their great truths by the strength of the human intellect, facts of this kind on which they must reason, are owing to the wonderful perfection of the human eye and hand, applied to produce combinations, which measure portions of space, formerly believed immeasurable by human powers.

MR. SOUTH,

I have great pleasure in presenting to you this medal. Receive it as the ancient olive crown (to use a metaphor

taken from the Olympic conquerors) of this Society; and it has a higher claim to this appellation, as belonging to arts of peace, which can only benefit mankind.

Researches of the kind, for which you receive this reward, if they have not the immediate effect or striking popularity of some other labours, yet are secure in their value, and sure of endurance. Other pursuits and successes may be connected with the passions, prejudices, and uneasy feelings of the day. These will outlive them; they require time for their complete development; they appeal to time for the meed of glory belonging to their discoverers.

Mr. South, your name is committed, as it were, to posterity, for more than ten centuries, in the largest period of revolution assigned to a double star: and it must be some satisfaction to you to know, that at so immense a distance of time, should our records remain, like those of Hipparchus and Ptolemy, when the brazen instruments with which you have observed are decayed, and the structure under which we stand crumbled into dust, your name is sure of being recalled with that of the two Herschels, by some accurate observer of the heavens.

I trust that this motive, as well as the nobler one of utility, will induce you to pursue and persevere in those researches, and steadily to apply your mind, your undivided attention, to this one great object, secure that you will reap abundant fruits from your labours, and that you will enjoy the pure pleasure resulting from the conviction, that you have increased the stores of human knowledge, and laboured not merely for those who are now living, but likewise for future generations.

[The following notices of three of the most distinguished chemists of modern times, and of Newton, the two Bacons, and of Pliny, may, it is hoped, be considered as deserving of a place in the author's Collected Works, although they are merely hasty sketches; and the more so, perhaps, on this account, as being thereby most likely to exhibit and express his current habitual feelings and sentiments on scientific excellence, the methods of science, and the peculiar merits of the individuals.]

[SKETCH OF THE CHARACTER OF DR. PRIESTLEY.*]

STIMULATED by the examples of Dr. Black and Mr. Cavendish, Dr. Priestley, about the year 1770, applied himself with intense ardour to experiments on the subject of air. By a constant application of the combinations and agencies of the various chemical substances, he discovered oxygen gas, nitrous gas, nitrous oxide, and light carburetted hydrogen; and by using the mercurial apparatus, he exhibited several of the acids in an aëriform state, and demonstrated their properties. As a discoverer, Dr. Priestley stands in the highest rank; and it is scarcely possible to advance a step, or to perform a process in pneumatic chemistry, without having recourse to his methods, and making use of substances he first exhibited. His activity was unceasing; and in physical science all his exertions were crowned with success. His experiments, though neither accurate nor minute, were almost always upon subjects of importance; he made up for the defect of his manipulations by the rapidity of execution, and the novelty of his methods. He prepared the way for more accomplished chemists; he furnished them with matter of inquiry; and, in the true spirit of liberality, offered to the world all his treasures of science. He was as the miner, who discovers hidden riches, and furnishes them in the unwrought state to the cunning

* [From a Chemical Lecture delivered in 1810.]

artist; the ore that he brought to light was crude, but it was precious and useful. To theory Dr Priestley paid but little attention; and his hypotheses were rapidly formed, and relinquished with an ardour almost peurile. His chemical writings are principally narrations of facts; and though the style and arrangement are defective, from hasty composition, yet it is impossible not to be amused and interested by his details. They are copious, distinct and satisfactory; and the manner in which they are pursued leaves a very favourable impression of the simplicity, the ingenuousness, and candour of his mind.

Dr. Priestley was a discoverer before he was a chemist. In a letter, which I received from him a few months before his death, he makes this statement, in his usual unaffected manner. It is easy, therefore, to find a reason for the occasional incorrectness of his views. Throughout the whole course of his life his attention was never undivided. His mornings were devoted to experiment; his evenings to political, theological, or metaphysical inquiries. He is an example how much may be done by small means, when applied with industry and ingenuity, and how easy it is, in some instances, to enlarge the boundaries of chemical knowledge; and how much more real and permanent glory is to be gained by pursuing the immutable in nature, than the transient and capricious in human opinion. When Dr. Priestley's name is mentioned in future ages, it will be as one of the most illustrious chemical discoverers of the eighteenth century.

[In the next lecture, the subject of which was nitrous gas, the author gives some further particulars of Dr. Priestley; and especially of the kind of apparatus

used by him. Having observed that he "knew no book so likely to lead a student into the path of discovery as Dr. Priestley's six volumes upon air," he continues:—]

His most important experiments were made with apparatus of the most simple kind. His grandest and most expensive instrument, like that of Dr. Hales, was a gun-barrel. He used phials and bent tubes for retorts; a wash-hand basin often served him for a pneumatic trough, and instead of porcelain tubes he employed tobacco pipes; and with this simple machinery he discovered a greater number of new substances than any philosopher of the last century.

[The next paragraph of the lecture, describing the manner in which nitrous gas was discovered by Dr. Priestley, may be considered deserving of insertion, as an example of the manner in which he made his discoveries, and as displaying the acumen of intellect of Mr. Cavendish.]

Dr. Hales has mentioned in his statical essays, that, during the solution of a mineral, which he calls Walton Pyrites, and which must have been a common pyrites, he procured air, which, when mixed with common air, gave a turbid red fume. Dr. Priestley, in mentioning to Mr. Cavendish that he wished much to witness the phenomenon, but that he despaired of ever procuring Walton Pyrites, was advised by Mr. Cavendish to try *any* pyrites, or metallic substances; for he had no doubt that the properties of the air depended upon the spirit of nitre, the nitrous acid, and not upon the substance dissolved. This hint led to the knowledge of the properties of a new elastic fluid: Dr. Priestley first procured nitrous air by dissolving brass in nitrous acid.

[OF SCHEELE.]

I have mentioned Scheele as an admirable experimenter. As, in the last lecture, I endeavoured to do justice to the philosophical labours of Cavendish and Priestley, I shall, with the same kind of feeling, refer to the exalted character of the only foreign philosopher of the last century, whose merits as a discoverer can be at all put in competition with those of our countrymen.

Scheele offers an extraordinary instance of the power of genius to conquer difficulties, and to create resources of its own. Born in a country town in Sweden, without friends, and without fortune, he seemed, by a disposition which may be called almost instinctive, to have pursued the study of chemistry. He was brought up as an apothecary and druggist; and led, by the circumstances of his business, to attend to some of the chemical qualities of substances employed in pharmacy, he instituted a train of investigations, which gradually led to discoveries of the noblest kind. Scheele, amidst the labours of an unprofitable occupation, found means of exalting and extending the more refined parts of chemistry. His days were devoted to a laborious business; his nights to solitary study. Using the common apparatus of pharmacy, he performed the most delicate manipulations, neither seeking fame nor profit by his labours; for, till he became acquainted with Bergman, he was ignorant of the honour which would result from discoveries: neither seeking fame nor profit, he pursued science, because his mind was imbued with an unquenchable desire for truth. Nothing could repress the ardour of his mind, nor damp

the fire of his genius; and his short life was a career of enterprise and of glory. Scheele made known at least thirteen new bodies; and his chemistry may be called almost his own creation. His theories were formed with boldness, but he attached no importance to *them* except as the mere links for the connection of facts. He was the faithful disciple of the school of Bacon and of Newton.

At the time that Scheele began his chemical labours, about 1772, Bergman, professor of chemistry at Upsal, was the great scientific luminary of Sweden. He had distinguished himself by some very profound investigations concerning chemical attraction, and had ascertained some important facts respecting metallic bodies and neutral salts. The manner in which Bergman brought forward Scheele, is highly honourable to the scientific character of the country. He wrote a preface for his first work, was his friend and protector; and, relinquishing the venerable authority of his chair, he became the disciple of a young man as yet unknown to the world. It has been said of Bergman, that 'his greatest discovery was the discovery of Scheele.' It may, perhaps, likewise, be said, that his greatest glory, was the glory of raising and exalting merit, even though it was in acknowledging his own inferiority. Such examples are very rare. There are few instances of such sacrifices of selfish feelings; and that they should be faithfully recorded, is necessary for the honour of human nature, and for demonstrating, to use the language of Bacon, borrowed from Scripture, that 'wisdom is justified of her children.'

[In another lecture, in which the author notices the character of Scheele, in similar terms of highest praise and admiration, he says:—]

I have been drawn into this eulogium, not merely because it is fully deserved, but because the example of Scheele demonstrates what great effects may be produced by small means; how little is required to extend the empire of knowledge, when genius is assisted by industry.

[OF PLINY THE ELDER.*]

[After having remarked that the philosophy of Rome was little more than an imperfect copy of that of Greece, the author proceeds:]

The only Roman who really deserved the title of an investigator into nature, was the elder Pliny. This illustrious person possessed the highest degree of industry, and an ardour in the pursuit of knowledge, which no difficulties could repress. He considered all the productions of the earth as worthy of attention, either for their order, their beauty, their uses, or relations to man. Possessed of such requisites for discovery, he was still deficient in the great characteristics of a strong mind and a philosophical spirit. Endowed with a simple heart, and, apparently incapable of deceiving, he believed almost whatever was related to him; doubt seemed to be a stranger to his understanding. He beheld things in their obvious forms, with delight and with wonder; and, satisfied with what he saw, he seldom attempted to refer effects to their causes. Endowed with none of the high elements of reason,—with none of those restless workings of the imagination, which produce new combinations of ideas, new truths, and new inventions,—he was, nevertheless, a minute

* [From an early Lecture on Geology, about 1804.]

observer and a faithful historian, but neither an experimental philosopher, nor a man of genius."

[OF LORD BACON.*]

[Of Lord Bacon, speaking of the period in which he lived, the author remarks:]

Many scientific persons, before Bacon, had pursued the method of experiment in all its precision,—many had dared to despise the logic and forms of the ancients; but he was the first philosopher who laid down plans for extending knowledge of universal application; who ventured to assert, that all the sciences could be nothing more than expressions or arrangements of facts; and that the first step towards the attainment of real discovery, was the humiliating confession of ignorance. Bacon was prepared, by nature, by education, and by his habit of study, for effecting the great revolution in philosophy. His knowledge was extensive; his instances were copious; his genius was equally capable of developing the lighter and more profound relations of things. He possessed a strong feeling, but it was uniformly directed by reason: he was gifted with a vivid imagination; but it was tempered and modified by a most correct taste and judgment. The influence of rank and of situation assisted his views. The public was prepared to receive them; and he was enabled to advance his opinions, in full confidence that they would be adopted with reverence in his own time, and that they would carry his memory into future ages with great and with unchanging glory.

[He immediately adds,]

* [From the same Lecture.]

The pursuit of the new method of investigation, in a very short time, wholly altered the face of every department of natural knowledge; but its influence was in no case more distinct than in the advancement of geology and chemistry. Though much labour had been bestowed upon these extensive fields of investigation, they had hitherto, as it has been seen, been little productive. Speculation had been misplaced, observation confined, and experiment principally directed, rather towards impossible, than to practical things. In the novel system, hypothesis was exploded, except as a guide to actual trials; combinations of thought were considered as truths, only when conformable to nature, and not when they merely expressed the caprices of the imagination; and those inquiries only were considered as valuable, which were made upon the hidden, sensible properties of things, and upon the existing relations of facts.

[OF THE ELDER BACON.*]

[Having pointed out that the elder Bacon was one of the first persons who applied himself to experiment in the dark period in which he lived, for the purpose of the advancement of science, and under the guidance of philosophical views; and that in his great work, he confessed he had gained the foundation of his knowledge from the Arabian writers, the author adds:]

This great man evidently studied nature, and the productions of the earth, with the views of a philosopher;—but his knowledge was so superior, as to be unintelligible in the age in which he lived; the wonders produced by chemistry, were referred by the people to

* [From the same Lecture.]

the agency of evil spirits; and a very short time after he had written a book to prove the non-existence of magic, he was himself persecuted as an enchanter; and he was imprisoned in 1278, by the command of the Principal of the Franciscans, for having brought the order to which he belonged into disrepute, by pretending to natural wisdom, and by exercising unholy and supernatural powers. Roger Bacon appears to have made use of the philosophical and experimental method of the Saracens, without following any of the absurdities of their doctrines. He had seen admirable changes produced on bodies, and he knew not the limits of the operations of nature. By him, the production of gold, and the transmutation of metals, were considered only as objects worthy of investigation; but he never affirmed confidently concerning them. He had made many important discoveries,—particularly that of an explosive compound, similar to gunpowder: and yet he seldom suffered his imagination to cloud his reason; and he was no enthusiast in regard to the merit of his inventions. He possessed the modest and dignified feeling of science. But most of the alchemists, who flourished in the next century, were of a very different complexion. They formed themselves into a fraternity; they professed to be in possession of great and important secrets; they connected a peculiar mysticism with their philosophical doctrines; they attached to alchemy a language similar to that which had been employed in the platonic philosophy; and they pretended, not only to a knowledge of the materials of the globe, and the changes of things, but likewise to an acquaintance with the elements and the spiritual powers by which they supposed they were governed.

[OF NEWTON.*]

There are, undoubtedly, in science, fortunate combinations; there are happy times, in which new inventions bestow new powers, and in which men are, as it were, compelled to follow an easy path to glory; but, for all this occasional interference of accident, labour—steady and *uninterrupted labour*—and the virtue of continued attention, are the true sources of noble and happy discoveries; and whoever possesses these enviable habits of mind, has the chief and the most certain elements of success. In the study of nature, there can be no exertion thrown away; for the general laws belonging to it, are no less simple and grand, than the economy which they govern is complicated and minute; and, when observation is carried as far as the senses can reach, it is still capable of being rendered more accurate, by means of the different apparatuses of instruments, which are constantly becoming more perfect; so that the philosopher who, having ascertained great truths in a particular department of science, should pretend to fix them as limits, would act as ridiculously as that Danish king, who commanded the ocean to stay its waves. When Newton was asked by Dr. Pemberton, to what he owed his great discoveries, he said to his habitual and patient attention; and the same great man, in a conversation in his later years, upon the progress of discovery, having asked, 'what was doing at Cambridge,' and being answered by Dr. Barrow, that 'there was nothing doing,' that he had 'occupied all the ground,' jocosely said, 'Beat the bushes, and there is still plenty of game to be raised.'

* [These reflections on Newton occur as a fragment in a note-book.]

Original profundity of genius, talents for abstracted research, and vigorous constitution of mind, combined with sagacity and acuteness, are undoubtedly associated with the powers by which lofty truths are attained; and they belonged, in the highest degree, to the author of the Principia, and the Optics; but these alone, though essential to the development of his abilities, would have accomplished nothing, without the faculty of continued exertion, which induced him to pass successive nights and days in contemplation, inattentive to the wants of the body; which enabled him to attain that sublime state of intellect, in which all sensible objects are excluded, and in which the mind was nourished by its own thoughts concerning the laws of the heavens and the earth made the subjects of active meditation.

By a singular concurrence of circumstances it was reserved for the same great genius who developed the laws of the planetary system, and who unfolded the harmonious movements of the great masses of matter in the universe,—it was reserved for Newton to lay the foundation of the first theory of chemical action, and to solve the diversified phenomena of corpuscular changes, by a great and universal principle, similar to that which he had before applied to the phenomena of the heavenly bodies. Newton, towards the close of his life, was made Master of the Mint; and that this office was once bestowed upon a man of science, was a great and glorious circumstance for the progress of chemistry. Newton performed the duties of Master of the Mint, and made a number of experiments upon metallic solutions and alloys. He discovered several new alloys, particularly that of a mixture which fuses at the heat of boiling water and which is composed of lead, tin, and bismuth. In reasoning upon the phenomena of

the dissolvent powers of acids, his sagacious mind at once perceived the extension of an order which prevailed with respect to the great arrangements of matter. Sugar dissolves in water, alkalies unite with acids, metals dissolve in acids. "Is not this," said Newton, "on account of an attraction between their particles? Copper, dissolved in aquafortis, is thrown down by iron. Is not this because the particles of the iron have a stronger attraction for the particles of the acid than those of copper? and do not different bodies attract each other with different degrees of force?" *

A principle, at once so beautiful and simple, and enforced by the authority of such a master, was immediately adopted. Geoffroy, the most able chemist in the Academy of Science, two years after Newton had published a complete development of his chemical opinions, attempted to make a table of chemical attractions, and to show, by numerical expressions, the powers which bodies have of separating each other from solvents. His manner of doing this was, however, far from being generous. He changed the name of *attraction* to that of *affinity*, and made no mention whatever of the original inventor in his paper. Though the principle was referred to Newton by Senac, who published an elementary book on chemistry, in French, in 1723; yet still the authority of Geoffroy, and his successors in the academy, who produced several popular elementary works on chemistry, influenced, in a higher degree, the public opinion, and for a long time the erroneous and vague term, affinity, was substituted for a word which implied the simple expression of a fact.

The greatness of the reputation of Newton, at this

* Newton's Works, 4to. vol. iv. p. 242. [This and the two following paragraphs, are from a Chemical Lecture of 1810.]

period, rendered his own countrymen almost indifferent to his claims in chemical philosophy. In the abundance of the rich stores which he afforded to science, such a small contribution was hardly missed. The controversy concerning the invention of fluxions was of a higher character; and the lustre of his mathematical philosophy, in some measure, threw his chemical discoveries into shade. But justice is the first principle of philosophical history. It is not with the vain idea of adding to the reputation of Newton, that I make these statements; not from the unworthy motive of expressing feelings of nationality; but for the sake of following truth, and of attributing glory where glory is justly due.

[OF MR. CAVENDISH.*]

Of all the philosophers of the present age, Mr. Cavendish was the one who combined, in the highest degree, a depth and extent of mathematical knowledge with delicacy and precision in the methods of experimental research. It may be said of him, what can, perhaps, hardly be said of any other person, that whatever he has done has been perfect at the moment of its production. His processes were all of a finished nature. Executed by the hand of a master, they required no correction; and though many of them were performed in the very infancy of chemical philosophy, yet their accuracy and their beauty have remained amidst the

* [From a Chemical Lecture delivered in 1810, shortly after Mr. Cavendish's death; it was in considering the progress of chemical discovery and the contributions made to it by this eminent philosopher, that the author digressed into the character of the man.]

progress of discovery, and their merits have been illustrated by discussion, and exalted by time.

In general, the most common motives which induce men to study are, the love of distinction, of glory, or the desire of power; and we have no right to object to motives of this kind; but it ought to be mentioned, in estimating the character of Mr. Cavendish, that *his* grand stimulus to exertion was evidently the love of truth and of knowledge. Unambitious, unassuming, it was with difficulty that he was persuaded to bring forward his important discoveries. He disliked notoriety, and he was, as it were, fearful of the voice of fame. His labours are recorded with the greatest dignity and simplicity, and in the fewest possible words, without parade or apology; and it seemed as if in publication he was performing, not what was a duty to himself, but what was a duty to the public. His life was devoted to science, and his social hours were passed amongst a few friends, principally members of the Royal Society. He was reserved to strangers; but, when he was familiar, his conversation was lively, and full of varied information. Upon all subjects of science he was luminous and profound; and in discussion wonderfully acute. Even to the very last week of his life, when he was nearly seventy-nine he retained his activity of body, and all his energy and sagacity of intellect. He was warmly interested in all new subjects of science; and several times in the course of the last year witnessed, or assisted in, some experiments which were carried on in this theatre, or in the laboratory below.

Since the death of Newton, if I may be permitted to give an opinion, England has sustained no scientific loss so great as that of Cavendish. Like his great predecessor, he died full of years and of glory. His

name will be an object of more veneration in future ages than at the present moment. Though it was unknown in the busy scenes of life, or in the popular discussions of the day, it will remain illustrious in the annals of science, which are as imperishable as that nature to which they belong; and it will be an immortal honour to his house, to his age, and to his country.*

[The author in his Introduction to the Elements of Chemical Philosophy, vol. iv. p. 30, alludes to Cavendish's two grand discoveries,—the composition of water and of nitric acid,—in a manner clearly indicating his conviction that Mr. Cavendish's claims to both were unquestionable. This I mention, with reference to the attempt which has been recently made by M. Arago, supported by Lord Brougham, to appropriate the merit due for one of these discoveries, that of the composition of water, solely to Mr. Watt. That the honour of the discovery was shared between these two illustrious men, has hitherto been commonly received; and that more is due to the latter, is neither proved, it appears to me, by M. Arago in his Eloge, nor by Lord Brougham in the supplementary article. The author's opinion on this important point, (important as it surely is in the history of science,) can hardly be considered but of great weight. Well acquainted with Mr. Cavendish and Mr. Watt, intimately acquainted with his son, Mr. Gregory Watt, in habits of daily intercourse with men of science, the contemporaries of the two former, as Sir Joseph Banks, Sir Charles Blagden, Dr. George Pearson and others,—he had the best opportunities not only of learning the current opinion on the subject, but also of ascertaining the truth. In one of his early

* [From the same Lecture.]

lectures, without date, but which from some remarks contained in it, may be inferred to have been written about 1806, there is a brief historical sketch of the discovery in question, which though evidently hastily written, may be deserving of insertion here, as a clear statement on the matter at issue.]

No natural substance [the author remarks] presents a more important series of investigations to the chemist and philosopher than water; the object so constantly presented to us; and the uses and effects of which are so familiar.

The appearances of this fluid are simple and uniform. And, when we consider the immense quantities in which it is found, and its almost universal agencies, it is easy to conceive how those ideas were formed, according to which it was so long supposed to be the most active and the most perfect of the elements.

"Water is the best," says the great lyric poet of the Greeks; and by this he evidently meant to express the doctrine of Thales, "that it was the great and active principle of Nature," an opinion which has been often supported; and which has appeared in some of the earlier theories of modern times.

Our knowledge of the true nature and effects of water is wholly derived from the discoveries of Pneumatic Chemistry. Till the year 1780, it was almost universally believed to be a simple body; and in tracing the history of opinion with regard to it before that period, we find only one conjecture which bears any relation to the truth; and that was formed by the unparalleled sagacity of Newton, who ventured to suppose from the high refractive powers of water that it must contain inflammable matter.

After the important properties of hydrogen gas had

been discovered by philosophers, experiments were continually made upon its combustion, both for the purpose of amusement and with the view of detecting the cause of the phenomena.

Various theories were invented: Scheele, who had performed the detonation of hydrogen and oxygen in open vessels only, and who found in these vessels after the process common air, supposed that the two gases had combined, and that their product was *heat*,—a bold conjecture, yet stamped by the genius of the *man*, and conformable to the observation which he had made; an observation imperfect from the want of proper apparatus.

Macquer as early as 1774 had observed that moisture was formed in the combustion of inflammable air; but this moisture was generally believed to be water which had been dissolved by the gas; and it was not till the summer of 1781, that the fact was perfectly understood. At this time Mr. Cavendish, in a process conceived with his usual sagacity, and executed with his usual precision, showed that when common air and hydrogen were exploded together in the proportion of 2½ to 1, the product was pure water, which exactly corresponded in weight to the gases consumed. And Mr. Watt, reasoning on this experiment, formed the conclusion "That water consisted of pure and inflammable air deprived of the greatest portion of their latent heat."

The discovery was generally admitted: and confirmed by the investigations of Lavoisier and the French chemists, it became the principal basis of that generalization which has been since called the antiphlogistic theory, and formed the most impressive and convincing fact of the doctrine.

Many of the experiments on the decomposition and

composition of water have been several times made in this theatre: and I am well aware that the appearances must be familiar to a part of my audience; but I may reasonably conjecture that many are present who have never witnessed them. In an elementary course on the operations of the chemistry of the gases it would be improper to omit so important and essential a series. I have witnessed them very often, I have performed them many times, and yet they seem always to afford me some new elucidations, some new subjects for inquiry, or some new object for speculation.

[In the opinion expressed by the author, there is no detraction; the fact of the discovery implying the inference is assigned to Mr. Cavendish; — the happy inference, independently made requiring to be confirmed to constitute a discovery, is assigned to Mr. Watt: — this was the decision of contemporaries, and with this Mr. Watt appears to have been contented. The contrary conclusion, it appears to me, cannot be sustained without involving consequences of the highest improbability,—implicating the character of Mr. Cavendish for truth, honour, and honesty,—implying a conspiracy against Mr. Watt, on the part of the Secretaries, President, and Council of the Royal Society,— and a want of courage and determination on the part of Mr. Watt and his friends, Dr. Priestley and Mr. De Luc, to come forward and vindicate his just claims. A dispassionate perusal of the writings bearing on the subject, and on collateral subjects of inquiry during that period of active research, especially the papers of Dr. Priestley, in the Philosophical Transactions for 1783 and 1785,—of Mr. Kirwan in the same Transactions for the intermediate year, and of Mr. Cavendish and of Mr. Watt in the same volume,—it

appears to me, can hardly fail to lead to that conclusion which is alike honourable to Mr. Watt and to Mr. Cavendish, and which is free from all the difficulties and painful consequences connected with the contrary.

According to my apprehension of the statements, the simple facts bearing on the question are the following. Dr. Priestley, in his paper on "the seeming conversion of water into air," bearing date Birmingham, April 21, 1783, distinctly mentions "an experiment of Mr. Cavendish concerning the re-conversion of air into water by decomposing it in conjunction with inflammable air;" a result which he confirmed by repetition.

This result, Mr. Watt states, was the basis of his hypothesis respecting the nature of water, and his first letter on the subject was written in the same month as Dr. Priestley's paper before alluded to; it was dated April 26, 1783. From a passage in Dr. Priestley's paper and in Mr. Watt's first letter, it may be inferred, that this his hypothetical conclusion was formed just before that letter was written; he mentions in it, the abandoning of an opinion that he had entertained for many years, "that air was a modification of water;" that by a great heat water might be converted into air.

Now, what is Mr. Cavendish's statement relative to the discovery? After describing his experiments in proof of the production of water by burning hydrogen in close vessels with common air and oxygen gas, he remarks:—"All the foregoing experiments, on the explosion of inflammable air with common and dephlogisticated air, except those which relate to the cause of the acid found in the water, were made in the summer of the year 1781, and were mentioned by me to Dr. Priestley, who in consequence made some experiments

of the same kind, as he relates in a paper printed in the preceding volume of the *Transactions*. During the last summer also, a friend of mine gave some account of them to M. Lavoisier, as well as of the conclusions drawn from them, that dephlogisticated air is only water deprived of phlogiston; but at that time so far was M. Lavoisier from thinking any such opinion warranted, that till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs should be converted into water. It is remarkable that neither of these gentlemen found any acid in the water produced by the combustion; which might proceed from the latter having burnt the two airs in a different manner from what I did; and from the former having used a different kind of inflammable air, namely that from charcoal, and perhaps having used a greater proportion of it."

This statement must be received either as correct, or the contrary. If the former, it is so precise in particulars, that there must be an end to all question relative to Mr. Cavendish being the original discoverer of the composition of water. If the latter, his conduct on the occasion must be pronounced to be dishonest and dishonourable, totally incompatible with all that is known of his character; and the same sentence must be passed on that of his friend, to whom he alludes, who was Sir Charles Blagden.

Lord Brougham, in the examination of evidence on the subject, seems to connect suspicion with the circumstance, which he has ascertained, that the paragraph above quoted was an addition to Mr. Cavendish's MS. paper, inserted, he presumes, with his consent, and as he supposes, by the Secretary of the Society, Sir Charles Blagden. Granted it were so; may it not, under the

circumstances of the case, be considered a confirmation of the accuracy of the statements it contains.

Taking for granted the honour and veracity of Mr. Cavendish, these circumstances appear to have been the following.

In consequence of an experiment of Mr. Warltire, in which a production of moisture appeared on exploding together common air and hydrogen gas, referred to by Mr. Cavendish, and the result of which was explained by the former, in the same manner as the similar result before obtained and similarly explained by Macquer, Mr. Cavendish, in 1781, made the experiments showing that water is the true product of the combustion of hydrogen and oxygen, and drew the inference, that water is composed of hydrogen and oxygen.

He makes Dr. Priestley acquainted with his results, as Dr. Priestley mentions. Dr. Priestley repeats the experiment, and obtains similar results. He communicates them to his friend Mr. Watt; Mr. Watt seems immediately to have seen their importance and bearing; and reasoning on them, to have given up his former opinion long entertained that water is convertible into air by great exaltation of temperature, and to have come to the conclusion "that water is composed of dephlogisticated air and phlogiston, deprived of part of their latent or elementary heat; that dephlogisticated or pure air is composed of water deprived of its phlogiston and united to elementary heat and light; and that the latter are contained in it in a latent state, so as not to be sensible to the thermometer or to the eye; and if light be only a modification of heat, or a circumstance attending it, or a component part of the inflammable air, then pure or dephlogisticated air is composed

of water deprived of its phlogiston and united to elementary heat."

These inferences were expressed in Mr. Watt's first letter, that to Dr. Priestley of the 27th April, 1783, which the latter, after showing it to several members of the Royal Society, placed in the hands of the President to be read at a meeting of the Society, but which was not read in consequence of the particular request of Mr. Watt to that effect, doubts as to the probability of his inferences having been raised in his mind, it would appear, by some new experiments of Dr. Priestley.

Whilst his paper is thus standing over, Mr. Cavendish brings forward his "experiments on air," those demonstrating the composition of water. This paper was read before the Royal Society January 15, 1784. Mr. Watt, it appears, had been previously urged, by his friend Mr. De Luc, to bring forward his hypothesis; and this he accordingly does in a letter addressed to this gentleman, dated Birmingham, November 26, 1783, prefacing it with the remark, "I feel much reluctance to lay my thoughts on these subjects before the public in their present undigested state, and without having been able to bring them to the test of such experiments as would confirm or refute them." This letter, in which was incorporated portions of his first letter, was read before the Royal Society on the 29th April, 1784, three months after Mr. Cavendish's, and before Mr. Cavendish's was printed.

Now, on the former presumption of Mr. Cavendish's truthfulness and honour, having made the discovery described in his paper, was it not perfectly natural that he should wish, and that his friend should wish, to insert a paragraph, stating what he had done in the inquiry in point of time, thereby establishing his right

to originality of discovery, both as to matter of fact and of inference, that is, that he saw water result from the burning of hydrogen gas, and inferred that water is composed of this gas and of oxygen; nor was it contrary to the usages of the Society to allow of the interpolation: the dates of the respective papers of Mr. Cavendish and of Mr. Watt were sufficient proof that the passage in question was an addition.

And, the manner in which Mr. Cavendish speaks of Mr. Watt's views, in another passage which was added, appears to me, on the same presumption of integrity on the part of the former, strongly confirmatory of the common opinion, that their conclusions were formed independent of each other. The passage is the following, and it is an excellent example of Mr. Cavendish's perspicuity and logical precision.

"From what has been said (having detailed his experiments), there seems the utmost reason to think, that dephlogisticated air is only water deprived of its phlogiston, and that inflammable air, as was before said, is either phlogisticated water, or else pure phlogiston; but, in all probability, the former.

"As Mr. Watt, in a paper lately read before this Society, supposes water to consist of dephlogisticated air and phlogiston, deprived of part of their latent heat, whereas I take no notice of the latter circumstance, it may be proper to mention, in a few words, the reason of this apparent difference between us. If there be any such thing as elementary heat, it must be allowed, that what Mr. Watt says is true; but, by the same rule, we ought to say, that the diluted mineral acids consist of the concentrated acids united to water, or deprived of part of their latent heat; that solution of sal ammoniac, and most other neutral salts, consist of the salt united

to water, and elementary heat; and a similar language ought to be used in speaking of almost all chemical combinations, as there are very few which are not attended with some increase or diminution of heat. Now I have chosen to avoid this form of speaking, both because I think it more likely that there is no such thing as elementary heat, and because saying so, in this instance, without using similar expressions, in speaking of other chemical unions, would be improper, and would lead to false ideas; and it may even admit of doubt, whether the doing it in general would not cause more trouble and perplexity than it is worth."

M. Arago, in advocating the cause of Mr. Watt, lays some stress on the manner in which Mr. Watt's hypothesis was received by the Council of the Royal Society, "Son *étrangeté* fait même douter de la vérité des expériences de Priestley. On va jusqu'à en *rire*, dit De Luc, *comme de l'explication de la dent d'or*."

Granted,—but this cannot apply to Mr. Cavendish, as the experiment of Priestley was merely a repetition of Mr. Cavendish's. Considering the peculiar shyness of this extraordinary man, and his great reserve, it is not surprising that the Council of the Royal Society should be as ignorant of the conclusion he drew from his experiment on the combustion of hydrogen, in which water appeared, as of the experiment itself.* His shyness and reserve, I have always understood were beyond all description. They are particularly noticed, in a

* [Mr. Cavendish at this time was not on the Council of the Royal Society; he was first elected on the Council in 1785.

From the Minutes of the Council it appears that Mr. Watt's letter was read before it came before the Committee of Papers, namely, on the 6th May, 1784, at one of the ordinary meetings of the Society, and was brought before the Committee on the 20th of the same month, when it was ordered to be printed together with a postscript.]

sketch of him by the author, one of the many which he amused himself in writing from recollection during his last illness, as has been already mentioned. It may be deserving of a place here; especially as it is perfectly in accordance with his character by the same hand, already given, though drawn in a different attitude, and with a different pencil, and in accordance with the idea, that he was a man of integrity, incapable of stooping to any meanness.]

Cavendish was a great man, with extraordinary singularities. His voice was squeaking, his manner nervous, he was afraid of strangers, and seemed, when embarrassed, even to articulate with difficulty. He wore the costume of our grandfathers: was enormously rich, but made no use of his wealth. He gave me once some bits of platinum, for my experiments, and came to see my results on the decomposition of the alkalies, and seemed to take an interest in them; but he encouraged no intimacy with any one. He left 15,000*l.* to Sir Charles Blagden by will, probably because they had once been great friends, and had ceased to be so. It is said that Sir Charles Blagden had early pecuniary obligations to Cavendish. He (Cavendish) lived, latterly, the life of a solitary, came to the Club dinner, and to the Royal Society, but received nobody at his own house. He was acute, sagacious, and profound, and, I think, the most accomplished British philosopher of his time. He was about eighty when he died.*

* [He died, I have been assured, in the most tranquil manner. A person employed by him about his apparatus told me that the last thing Mr. Cavendish called for, was a glass of water, and then he desired to be alone: his attendant being uneasy respecting his state, retired to a distant part of the room. Mr. Cavendish drank some of the water, turned on his side, and shortly expired, without uttering a word or even a sound, much in the manner of his illustrious contemporary Dr. Black, who died

[A few pages back the author's intimacy with Mr. Gregory Watt has been alluded to; in the first volume, the circumstances under which it was formed have been described; in a geological lecture delivered in 1811, in referring to Mr. Gregory Watt's experiments on the fusion and slow cooling of basalt, and his paper on the subject, "abounding in acute observations and sagacious inferences," which was published in the Philosophical Transactions; he adds,] It was the first and only geological production of a mind full of talent and enthusiasm for scientific pursuits — of a mind which promised much for the philosophy of this subject; but death cut off this bloom of promise and hope for the scientific world at the moment when it was brightest. No person attached to truth can read his paper without a feeling of regret, and I hope I may be excused for the strong expression of this regret, for whilst I admired him as a philsopher, I loved him as a man. He was the earliest and one of the dearest of my scientific friends.

[The author's respect for the illustrious father, was expressed on very many occasions, but on no one more powerfully than at that memorable meeting which was held at Freemason's Hall, in London, on the 18th June, 1824, for erecting a monument to Mr. Watt, at which Lord Liverpool, then Prime Minister presided, and at which some of the most distinguished men in the country, came forward, and in speeches of glowing eloquence, which it is difficult now to read without emotion, bore testimony to the merits of the man and of the philosopher, and of his extraordinary claims to the

as if he had fallen asleep, with an unspilled basin of milk on his knees, sitting in his chair. Vide the interesting account of the event in Dr. Robinson's Preface to Dr. Black's Lectures.]

gratitude of his country, and of the world. It was on this occasion, feelingly designated by Sir Robert Peel, as an "awful and affecting occasion," and happily called by Sir James Mackintosh "a public solemnity in honour of the useful arts;" and which Mr. Wilberforce, in his best manner of philosophical benevolence contrasting with other meetings of political and party debate and contention to which they were accustomed, characterized as one, where "we seem to rise into a higher region of light and truth, of genius and of science, where none of those passions darken and none of those baser emotions discompose the atmosphere, that are generated in the scufflings of the vale below,"—it was on this occasion, which it is really delightful to dwell on, that the author in moving the first resolution, thus addressed the meeting.]

I ought to apologize for rising so immediately to address this meeting, but as the distinguished person whose memory we have met together to honour, owes his claims to the gratitude of society to his scientific labours, and as he was one of the most illustrious Fellows of that Institution for the promotion of natural knowledge over which I have the honour to preside, I consider it as a duty incumbent on me to endeavour to set forth his peculiar and exalted merits, which live in the recollection of his contemporaries, and will transmit his name with immortal glory to posterity. Those who consider James Watt only as a great practical mechanic, form a very erroneous idea of his character,—he was equally distinguished as a natural philosopher and a chemist, and his inventions demonstrate his profound knowledge of those sciences, and that peculiar characteristic of genius, the union of them for practical application. The steam engine, before his time, was a rude

machine, the result of simple experiments on the compression of the atmosphere, and the condensation of steam. Mr. Watt's improvements were not produced by accidental circumstances, or by a single ingenious thought, they were founded on delicate and refined experiments connected with the discoveries of Dr. Black. He had to investigate the cause of the cold produced by evaporation, of the heat occasioned by the condensation of steam; to determine the source of the air appearing when water was acted upon by an exhausting power; the ratio of the volume of steam to its generating water, and the law by which the elasticity of steam increased with the temperature; labour, time, numerous and difficult experiments were required for the ultimate result; and when his principle was obtained, the application of it to produce the movement of machinery demanded a new species of intellectual and experimental labour. He engaged in this with all the ardour which success inspires, and was obliged to bring all the mechanical powers into play, and all the resources of his own fertile mind into exertion; he had to convert rectilinear into rotatory motion, and to invent parallel motion. After years of intense labour he obtained what he wished for; and at last, by the regulating centrifugal force of the *governor*, placed the machine entirely under the power of the mechanic, and gave perfection to a series of combinations unrivalled for the genius and sagacity displayed in their invention, and for the new power they have given to civilized man.

Upon the nature of this power I can hardly venture to speak; so extensive and magnificent a subject demands a more accomplished and able orator. What is written on the monument of another illustrious and kindred

philosopher* in relation to one great work, and a single spot will apply to Watt in almost every part of the empire: —

"Si monumentum requiris, circumspice."

And where can we cast our eyes, without seeing results dependent upon, or connected with his inventions? Look round on the metropolis; our towns, even our villages; our dock-yards, and our manufactories; examine the subterraneous cavities below the surface, and the works above; contemplate our rivers and our canals, and the seas which surround our shores, and every where will be found records of the eternal benefits conferred on us by this great man. Our mines are drained, their products collected, the materials for our bridges raised; the piles for their foundation sunk by the same power; machinery of every kind, which formerly required an immensity of human labour, is now easily moved by steam; and a force equal to that of five hundred men is commanded by an infant, whose single hand governs the grandest operations. The most laborious works, such as the sawing of stones and wood, and raising of water are effected by the same means which produce the most minute ornamental and elegant forms. The anchor is forged, the die is struck, the metal polished, the toy modelled, by this stupendous and universally applicable power: and the same giant arms twist the cable rope, the protector of the largest ship of the line, and spin the gossamer-like threads

* [The inscription above alluded to, is that in St. Paul's on the monument of Sir Christopher Wren; it is as follows:—

SUBTUS · CONDITUR · HUIUS · ECCLESIÆ · ET · URBIS
CONDITOR · CHRISTOPHORUS · WREN · QUI · VIXIT
ANNOS · ULTRA · NONAGINTA · NON · SIBI · SED
BONO-PUBLICO · LECTOR · SI · MONUMENTUM · REQUIRIS
CIRCUMSPICE.]

which are to ornament female beauty. Not only have new arts and new resources been provided for civilized man by these grand results, but even the elements have to a certain extent been subdued and made subservient to his uses; and by a kind of philosopical magic, the ship moves rapidly on the calm ocean, makes way against the most powerful stream, and secures her course, and reaches her destination even though opposed by tide and storm.

The Archimedes of the ancient world by his mechanical inventions, arrested the course of the Romans, and stayed for a time the downfall of his country. How much more has our modern Archimedes done? He has permanently elevated the strength and wealth of this great empire, and during the last long war, his inventions and their application were amongst the great means which enabled Britain to display power and resources so infinitely above what might have been expected from the numerical strength of her population. Archimedes valued principally abstract science: James Watt, on the contrary, brought every principle to some practical use; and as it were made science descend from heaven to earth. The great inventions of the Syracusan died with him, those of our philosopher live, and their utility and importance are daily more felt; they are among the grand results which placed civilized above savage man,—which secure the triumph of intellect, and exalt genius and moral force over mere brutal strength, courage, and numbers. The memory of James Watt will live as long as civilised society exists; but it surely becomes us who have been improved by his labours, — who have wondered at his talents and respected his virtues, to offer some signal testimony of our admiration of this great man. This, indeed, can-

not exalt his glory, but it may teach those who come after us that we are not deficient in gratitude to so great and signal a benefactor. I, therefore, my lord, beg leave to move, "That the late James Watt, by the profound science and original genius displayed in his admirable inventions, has, more than any other man of this age, exemplified the practical utility of knowledge, enlarged the power of man over the external world, and both multiplied and diffused the conveniences and enjoyments of human life.

[Neither in this speech, nor in any of the others delivered at the same meeting, is there any allusion made to Mr. Watt as the discoverer of the chemical composition of water; by every speaker the subject is entirely passed over, which surely on such an occasion, is not what might have been expected, if the merit of the discovery was truly his and not Mr. Cavendish's, and if it had been supposed that justice had not been done to the former.]

[In the First volume, page 99, allusion has been made to the manner in which the author spent his time, when not engaged in research in the laboratory, especially during the summer vacations, and how in his excursions into the country, he combined with recreation for the sake of health, the study of geology and agriculture. As an example of his manner of proceeding on these occasions, it may not be amiss to insert a portion of a Journal of a tour which he made in Ireland, in the early summer of 1806, showing, as it does, the objects for which he travelled, and the systematic mnnner in which he observed; and perhaps for another reason, as it conveys the impression made on his mind by the country and people in districts in many respects peculiar and out of the track of ordinary tourists. The reader should keep in recollection, that the journal was intended solely for his own use; that it was never copied by the author, or even looked over for correction; and in brief, that it is composed merely of rough notes, some of which, in consequence of the haste in which they were written, it is difficult to decipher. The journal is a fragment, and commences at Limerick :—]

Limerick, June 27.

1. The journey from Rathkeal to Limerick, without many objects of interest. Small hills, without

wood; plains covered with bog for many miles. Adare is the first place calculated to arrest the attention of the traveller. Here is wood, fine trees, and some monastic buildings beautiful in their ruins. The architecture, where it retains its characteristics, Gothic; the walls covered with ivy: a scene denoting ancient splendour, whilst the cabins which surround the walls tell a tale of existing wretchedness.

Within four miles of Limerick, a mountain scene is developed. The Keeper chain to the east, the Clare hills to the north; their forms smooth and generally rounded, and the most lengthened inclination to the west.

Limerick. — A large well-built city. The Shannon, a fine river; but, though affected by the tide, certainly inferior in size (perhaps even in the quantity of water it sends down) to the Thames and the Severn, at equal distances from the sea.

Marks of improvement. — Good buildings rising; a handsome race of people, and more pretty young women than I have seen since our departure from London; a fine fall of the Shannon, when the tide is down; and a river about a mile above it, where salmon are caught in abundance. Limerick might be imagined an English town by those who had no dealing with the keepers of the inns and of livery stables. No beautiful or grand scenery about this city. The banks of the Shannon bare, or but little wooded; and no remarkable character in the river, if the extreme clearness and purity of the water be excepted. From Limerick to Nenagh, a road through a cultivated country. Views from the Shannon, and some fine effects from the Keeper mountains.

2. Geology of Limerick, and the mountains bor-

dering upon it:—Sandstone, schist and sandstone occur near Rathkeal, and shell limestone is abundant, on all the road from Killarney to Limerick. Several quarries have been opened. The character of the rock is distinct; much mechanical deposit and little crystalline matter. The colour dark brown, grey, or black. Coal-blend occurs between Killarney and Abbey Feale, probably beneath the sandstone slate. The limestone inclined very little. The strata numerous and parallel; the upper exceedingly broken and decomposed, and the dip, where it could be distinctly perceived, to the south. The shells more abundant in the upper strata.

These secondary strata probably thrown out of their horizontal position at the same time with the elder strata. Like the elder strata of Kerry, they are often curved. The curvature of the shell limestone distinct in the road to Abbey Feale, but not upon so great a scale as at Ross Island.

The limestone about Limerick shell-rock, and probably in parallel layers. The surrounding mountains afford the same substance, with sandstone and slate and pebble-stone; probably the slate lowest, then the pebble-stone, then the limestone.

The Keeper range of mountains, from the smoothness of their outline, and from the detached stones, are probably of similar constitution; that worked for the lead mines, called Silver Mines, afforded, on examination, similar facts. A few detached stones of granite and sienite on the side of this mountain. A miner told us such occurred in the Keeper; but, as the greatest part of this mountain is grit and limestone, I suspect he has mistaken pebble-stone for primary rock, and that the sienite and granite are from the mountains of Kildare or Carlin. Amongst the line of moun-

tains to the east of Nenagh, is a mountain most singularly indented, called the "Devil's Bite," and traditionally said to be a road made for the devil and his goats. It is a great limestone rock (i.e. I am told so). The appearance is probably owing to a sudden sinking of a great portion of a parallel stratum, and the rock, I conceive, must be shell-rock. The fact is the more singular, as the surrounding mountains are gently rounded, but this presents only straight lines.

3. Land well cultivated for Ireland; much pasture, but no irrigation; not much liming; the soil very calcareous; wheat and barley, but little flax.

4. The lower classes poorly clad, and nearly as miserable as those of Cork. No marks of that enthusiasm of character which sometimes occurs in Ireland. Idleness without thought, and the old association of ignorance and impudence. Miserable articles of Irish manufacture, spoken of by their vendors as superlative. The Limerick hooks and flies altogether fallen off, very bad, and very expensive; yet every paltry fisherman considers himself as the best fly-tyer "in Limerick, in Dublin, in all Ireland, ay, and in England too—ay, and in the whole world"—having "the best colours, making the *naitest* hook, and having the quickest eye and the naitest hand."

The shops well furnished with English manufactures. All comforts, all luxuries, all spirit of improvement, all that makes Ireland important and respectable, are either of foreign growth or of foreign education. The great vice of the people is want of perseverance: nothing is finished; they begin grandly and magnificently, but complete very little. In mining, they build machinery before they have discovered a vein; in the fisheries, they erect their

cellars before they have purchased nets; and they build magnificent stables, which they intend for their studs, but which they are themselves obliged to inhabit. Foresight and prudence are unknown.

Edgeworth Town. — First aspect of the country between Nenagh and Edgeworth Town flat, bare, and without any objects of beauty. The course of the Shannon is through a flat country; its banks bare and reedy; its current slow; sometimes deep and still, and confined within shores of one hundred yards, at other times expanded into lakes, with islands. No mountains; hills so rare, that a woman at Athlone, recommending us to take four horses on account of the *hills*, said they were "terrible hills, very high, as high, ay, and higher too, than the house," which was an exceedingly low edifice of two stories. The Shannon at Portumna is deep, but rapidly spreads out in its course into a great loch. At Banagher it is rapid below the bridge, and at Athlone still more rapid, and not more than fifty yards over. The little river Inny runs by Ballinachur. Here are hills, but no wood, and bog or grass land, with some arable. Flax and barley, and a little wheat.

The country about Edgeworth Town flat, but an amphitheatre of hills surrounding the plain. None of them very high, probably all less than 1000 feet. One hill, the hill of Ardar, we ascended, and saw a great extent of ground: the quiet Shannon rolling sleepily and slowly through green meadows and brown bogs, to the south: to the west, a great range of very distant mountains; to the north the hills of Westmeath, low and rounded; to the east, fog, where, in a clear day, we might have seen the mountains of Wicklow.

2. Limestone, sandstone, and puddingstone, in various associations.

3. Except the moral and intellectual paradise of the author of "Castle Rackrent," nothing worthy of observation.

4. The county of Westmeath and that of Longford abound in small lakes, which are surrounded by bogs; and in the shores of them, in dry seasons, the horns and bones of deer are discovered in great abundance. This country, now so bare, was anciently an immense forest; and it is an object which might employ speculation as worthily as many other objects, whether the great change was owing to the slow operations of nature, decay, or to some great convulsion or inundation.

Donegal, July 17.

1. Aspect of the country from Edgeworth Town to Belturbet, without any marked traits of beauty; some hills to the south possessing a varied outline, but a general want of wood; green and cultivated fields, bogs and heath land.

From Belturbet to Enniskillen an exceedingly beautiful country. The Erne appears, at Belturbet, immediately in the town, a rapid torrent, but becoming a lake above and below. The access to Loch Erne is through rounded hills, green with pasture; few trees. From the top of the hill, about eight miles from Belturbet, the lake appears a noble expanse of water, with many wooded islands. A green and cultivated hill, of most graceful form, the principal near object, and some blue mountains in the back-ground, tabular and smooth; a view of great extent, soft and quiet, without rudeness of form or strong contrast of colouring, yet impressive from its magnitude, from

the variety of land and water, and from the beauty of cultivation. A number of lakes of various sizes, few exceeding two miles in circumference, border the upper part of Loch Erne, and pour their waters into the Upper Erne; but the banks of most of them are boggy. There is no rock-scenery, and few trees. At Enniskillen the Upper Loch Erne is joined to the Lower by two streams crossed by bridges, and the town stands in the island formed by them. The road from Enniskillen to Ballyshannon is exceedingly beautiful. Views of Loch Erne, studded with green islands, and bounded by blue mountains, to the east; on the west and south, hills covered in some parts with wood, and exhibiting in most parts trees just beginning to throw out young shoots from their lopped trunks. About Church Hill, to the north, a small lake, surrounded by very grand mountain scenery, indented rocks, disposed in some parts in horizontal layers, forming the western boundary; green mountains, presenting here and there blue and yellow cliffs; and in the distance a great surface of bare rock, not less than 700 or 800 feet above the lake. The mountains on the south extending from the Upper Loch Erne to Sligo, all similar in form, and presenting immense layers of rocks, having bright green slopes at their bases, and immense gulleys cut from the top to the bottom. Their outline is made up of straight and jagged lines; their side often nearly perpendicular, and the highest probably considerably above 2000 feet. The first view of Loch Erne is at about five miles from Church Hill. Here the mountain cliffs of Leitrim form a grand outline to the south; and the mountains of Fermanagh, composed of irregular masses of bright brown rock, covered with heath, and at the feet green

with grass, appear to the north and east, rising boldly out of the lake's wooded promontories; hills repose beyond them, and the great expanse of water is broken by an immense number of islands, all of soft and curved forms, and for the most part finely wooded; in the northern distance, the blue mountains of Fermanagh, and further west, those of Donegal.

The Erne runs rapidly over dark layers of rock into the sea at Ballyshannon; its banks are but little wooded, but it is a noble river, a succession of small cataracts; and its last and greatest fall is a wild and sublime scene. The river precipitates itself over jagged, broken, stratified rocks, into the Atlantic: white foam, and brown water, and black rock, and the blue sea, are the prime objects: the scene is the more impressive from the simplicity of its parts. From the hill above Ballyshannon appear, to the south, the hills of Sligo and of Leitrim, bold and fantastic in form; Benvallen, a pyramidical mountain, appearing almost immediately above the town, and yet it is said to be twenty miles distant: Cape Tillen, to the west, a noble mass of mountain, grand and indistinct; the hills to the north of very fine outlines, and colouring bright brown, bare, and apparently producing nothing but moss.

The road from Ballyshannon to Donegal over green hills; no trees. The bare rocks and mountains having their summits sometimes disclosed, and sometimes hidden in mist, in the background. The river Esk, a fine mountain torrent; but without wood on its banks, and having nothing to recommend it but the wildness of its surrounding scenery.

2. People more civilised than in the midland counties, or in Kerry; better dressed, and more

beauty of person. Protestants becoming more numerous as we advanced further north; still considerable religious feuds. We passed from Belturbet to Enniskillen on the 12th of July, the day of King William's triumph, and we heard and saw much riot; processions of men with the orange lily in their hats, women wearing this flower as a nosegay. The liberty of wearing it interdicted to the Catholics; a sign by which the Orangemen are still known. At night there is generally a battle between the two parties. The Catholic soldiers at Enniskillen, the Limerick militia, did not fire on this day, but the Protestant regiments always do. Ballyshannon is a truly Irish town—high houses, good in exterior, wretched internally; peats stopping up the windows: broken glass; no sashes to be found.

8. Course of crops.—Potatoes, oats, barley: this about Loch Erne. Further north a more enlightened system. At Ramelton, in Donegal, potatoes, barley, oats, flax. After seven years, usually a fallow; then grass seed is sown, and three years taken in grass. Manure with the potatoes, never with the flax. Shell-sand used, particularly after fallow. Flax the staple commodity of the country.

Geology of Fermanagh, Cavan, Leitrim, Donegal.

In Cavan, about Ballinaght, a granitic schistose country. The granite associated with grawaké schist and porphyry, and probably of the first family of secondary rock. The schist, composed of compact felspar and chlorite, with a little mica: the porphyry having a base of compact felspar, and much decomposed, and where decomposed white. Beyond Cavan the secondary strata again occur, and continue to Ballyshannon,

where the first micaceous schist in the west and north of Ireland occurs, at least as far as our knowledge extends. Limestone and sandstone at Belturbet; limestone dipping to the west, and abounding in shells and coral of different kinds; limestone occupying the greatest part of the subsoil in the road to Enniskillen, and an immense number of layers, in general parallel to the horizon. At Church Hill, cliffs of a limestone of considerable consolidation. The mountains of Leitrim, composed of parallel layers of limestone and sandstone; basaltic bolder-stones, probably from dykes.

At Ballyshannon the Erne falls over limestone rocks, and a fine crystallised magnesian limestone occupies the lowest strata on the banks of the Erne; and this limestone contains rhomboidal spathose crystals, and quartz crystals, in great abundance; and above it is a limestone full of corals, alternating with a carbonaceous shale, but no coal visible. Coal will probably be found in abundance in the lowest part of the Leitrim mountains, as the strata are of the carboniferous family.

The high mountains of Donegal are, probably, all micaceous schist, or granite, or sienite, at least in this part.

In the mountain road through the Barnesmore-gap, high mountains of granite, with comparatively little mica, constratified and massy in formation. Lower, micaceous schist, of beautiful varieties; a number of species of gneiss; tumblers of trap and sienite; a few quartz veins in the granite, and some veins of quartz and of calcareous spar in the gneiss above Donegal: no chlorite, metalliferous indications in these mountains."

Donegal, July 19.

Ramelton. — Road from Ballyshannon to Donegal exceedingly wild; rude mountains to the north and

west; green hills around the course of road; views of Cape Tillen, and of the mountain capes stretching into the Atlantic, and the mountains of Leitrim south, stratified, and presenting a striking contrast to the rude massive rocks of Donegal.

At Ballybofey, the river Finn, a large mountain stream, at this time brown from floods; wooded hills on the west; bare brown curved hills on the east and north-east. From Ballybofey to Litterkenny, a very wild road; a great chain of mountains to the north and north-west; the Arrigle and Muckrish. The summit of Arrigle peaked, and rising acutely pyramidical; that of Muckrish tabular. The valleys wild, and but little cultivated; very few trees; grey rock, heath, and the sides of gulleys covered with lively green herbage.

From Ballybofey to Ramelton, a very fine and impressive assemblage of scenery. Loch Swilly, a fine expanse of salt water, bounded in front by green habitable hills; a few groups of trees on the very edge of the water; in the distance high and wild mountains; two peculiar, marked in outline and height, tabular and rounded; the most northern, Ossian's Mount. On the west and north, magnificent views of the Arrigle and Muckrish chain, indistinct, blue, rising amongst the clouds, which are rolling about their sides and summits; irregular craggy hills, chiefly bare rocks, below them.

Ramelton, seated on the banks of a beautiful river, immediately discharging itself into Loch Swilly; trees on the banks of the water; distant mountains above, and parts of the loch, with its beautiful boundaries, visible from all the streets of the village.

2. The best race of people that has appeared in the course of the journey; civility, with independence of spirit; no marks of the broken reed of rebellion; no

crouching, but much dignity and simplicity; yet the potatoe grows even amongst the mountains of the Finns, and the unquiet and uncertain spirit now and then breaks forth. I witnessed the humours of a crowd at Ramelton, assembled after having seen a pony race. A great number of men and women jostled together in the narrow streets of a little town, without any other object than that of pushing each other; every room in every house filled with people, enjoying whiskey and tobacco; beggars, wherever there was a standing, or a sitting, or a lying place; a number of drunken horse and foot passengers; much finery of dress, but a number of persons, who seemed rather to have wished to appear magnificent than to know how to produce the effect; a profusion of ribands and of white linens; not much beauty of person. A great fight took place after the fair (an event that is always hoped for, and expected), and a number of heads were broken, and much blood, inflamed by whiskey, shed, but no lives absolutely lost; one man was 'twice killed' by another, knocked down, and the head twice cut. He was a Litterkenny boy, and had offended the oppressing hero, by saying, 'Ay! and is not the boy of Latterkenny as good as the Ramelton boy, at cutting a bog or at heaving the peat?' Many traditional stories of the giant race of the Finns, and their chieftain, Finmacoul; and Gaelic songs are said to be remembered and recited by the old men in the wild glens of Muckrish and Arrigle.

3. *Geology.*— Granite and micaceous schist, and a great variety of sienites about Ballybofey. The inclination of the micaceous schist appeared to me to be uniformly to the north. Limestone about a mile from Ballybofey; carbonate of lime, with much mica, stratified and directed to the north; alternate layers, in the

principal quarry, of a compact siliceous rock and crystallized carbonate of lime, and, the carbonate of lime having been washed out at the surface, the rock appears ribbed: much curvature, both of the siliceous rock and the marble veins of quartz and of calcareous spar cutting the limestone, and specks of copper and much pyrites in the veins; lower is a more compact marble; the upper marble is splintering in fracture, but this is nearer Carrara marble: this, probably, a great dyke of the same formation as the Killarney marble, filling a chasm in the micaceous schist.

From Ballybofey to Ramelton, a similar constitution of country, similar inclination, curvature of strata, and immediately by Loch Swilly, great abundance of a micaceous schist, principally composed of quartz.

In the mountains above Loch Foyle, and by Loch Salt, marble of elder formation, and a rock approaching very nearly to serpentine in its character, but composed of hornblende, felspar, and a little chlorite. The high mountains about Loch Salt, sienite and quartz rock; no regular inclination, but a distinct stratification, and much disturbance and curvature: the limestone beds inclined to the south.

In the general arrangement about Loch Swilly, the micaceous schist occupies the lowest position; above this is a stratified rock, principally consisting of marble, with a little mica, and exceedingly incurvated; and upon these occur the beds of limestone, which, in several instances, are in absolute contact and union with micaceous schist, and contain mica in abundance; at the top of all, sienite of different kinds: the felspar and mica exceedingly white, and very decomposable: and quartz rocks crystalline, and having the greasy fracture.

Muckrish, said to be composed of quartz-rock. The

quartzose sand belonging to it has probably resulted from the decomposition of a compound rock of quartz and felspar.

The immense proportion of quartz in the mountains of this district is a fact which can hardly be explained by any application, however forced, of the Huttonian theory. Pressure cannot interfere where the material is simple, and where no elastic matter is present; and to suppose any terrene solvent, which has afterwards been separated, will not coincide with the known laws of chemical affinity.

Sunday, July 22.

1. The morning of this day I spent in a ride to the mountain district of Donegal. From Ramelton to Nilmacrenan, wildness in the fore-ground, and in the back-ground bogs, and bare rocks in the valley. The sides of the hills only cultivated, and the summits partly coloured, brown heath, and grey or white rock.

At Loch Salt, three miles from Nilmacrenan, a grand view. The Atlantic to the north-west, with a variety of salt-water lochs washing the feet of bleak mountains; fresh-water lochs nearer, in the cavities of the mountains. Amongst these, Loch Salt wonderfully magnificent; breasted by a mountain to the east, at least a thousand feet high, and principally composed of rocks so white as to seem covered with snow; to the west, green hills with curved rocks, and a singular assemblage of decomposed and water-worn stones; and to the south an almost perpendicular precipice.

From the summit of the mountain above Loch Salt, the wildest scene in Ireland, Muckrish and Arrigle, having their summits peeping above the clouds; distant, yet only so distant that the great gulleys of Arrigle and its yellow colouring were visible, and the dark heath of

Muckrish, and its white seams of sand: between the intermediate mountains, precipices of rock, green hills, and dark lakes, with torrents pouring down the sides of mountains, whose summits were hidden in rain clouds. Sunshine appeared on some spots, whilst black clouds covered others; and, in the space of ten minutes, the spot on which I stood had been wet and dry.*

* [The following lines, descriptive of these mountains, were, I believe, written about the same time as the above, as also those which succeed them, on Fair Head; they are given as another example of the poetical temperament of the author, and of his disposition to express in verse what strongly impressed his mind:—]

Muckrish, and Arokil, ye pair
Of mighty brethren, rising fair
  Amidst the summer evening's western light:
Clouds might ye be, so bright your hue,
So dense your purple in the blue
  That ushers in the night,

Were ye not motionless; your forms
Unchanged by breezes or by storms,
  The same from day to day, from age to age,
Unalter'd midst the wrecks of time,
Scorning in giant strength sublime
  The whirlwind's and the lightning's rage.

Summer's wild heathblasts, winter's snows,
Disturb not your supreme repose:
  Not the mild influence of spring,
Clothing the lowlands all in green,
Creating round a joyful scene
  Of change to you can bring.

Not e'en the purple heath expands
Its foliage o'er your blanched sands;
  Your rocks alone the yellow lichen covers,
In palest tints, and o'er the space ye own,
No shapes of life are known,
  Save where the eagle hovers.

His screams, the mountain torrents' sound,
The mountain breezes whistling round,
  The distant murmurs of the western wave,

2. Amongst these mountains, I met with a singular race of beings,—the most gifted with vague curiosity of any men I have seen. They asked questions without considering whether they were civil or uncivil, and seemed little daunted by reproof.—*Q.* 'Where do you come from?' *A.* 'Ramelton.'—'Do you belong there?'

Compose the music wild and rude
Of your unhaunted solitude,
  Else silent as the grave.

The glens that ranged around your feet
In grand confusion seem to meet
  As with your parts to harmonise,
While they your fountains drink,
In kindred wildness sink
  As ye in wildness rise.

But, chiefly thee, Fair Head!
Unrivall'd in thy form and majesty!
Far on thy loftiest summit I have walked
In the bright sunshine, while beneath thee roll'd
The clouds in purest splendour, hiding now
The ocean and his islands, parting now
As if reluctantly; whilst full in view
The blue tide wildly roll'd, skirted with foam,
And bounded by the green and smiling land,
The dim pale mountains and the purple sky.
Majestic cliff! thou birth of unknown time,
Long had the billows beat thee, long the waves
Rush'd o'er thy hollow'd rocks, ere life adorn'd
Thy broken surface, ere the yellow moss
Had tinted thee, or the wild dews of heaven
Clothed thee with verdure, or the eagles made
Thy caves their aëry. So in after time
Long shalt thou rest unalter'd mid the wreck
Of all the mightiness of human works;
For not the lightning, nor the whirlwind's force,
Nor all the waves of ocean shall prevail
Against thy giant strength, and thou shalt stand
Till the Almighty voice which bade thee rise
Shall bid thee fall.

'No.'—'What place do you belong?' 'London.'—'Is it war or peace?' 'War.'—'Have the English lost any men?' 'There has been no battle lately.'—'When was the last?' 'Lord Nelson's; did you never hear of him?'—'No. What is your name?' 'It is a name you have never heard of, and never will hear of?'—The dialect and accent not similar to the Irish, but rather pure English, with many interlardings of unmeaning expressions, the most favourite of which was 'Teagues.' They all agreed that there were old men who knew the history of the Finns and Finn Macoul, in Gaelic; but no one could show me the abode of these sages.

Four religions—a mountain religion (Covenanters), a Scotch kirk, a Romish church, and an English church. The kirk exceedingly troublesome, and great enemies to Sabbath-breakers. A man hot with whiskey, and with the Presbyterian spirit, took away my rod on Sunday evening. The people of the town seemed to resent the injury, but rather too mildly. The people are in a state scarcely as yet prepared for improvement; the middling classes having rude hospitality, the lowest barbarous: gratitude, however, was striking. A boy applied to me for medicine; I prescribed for him, gave him physic, and, what was better, money: his gratitude was of the nobler kind. It is only in towns that the lower classes are depraved.

Newtown Limavaddy, July 24.

1. The road from Ramelton to Raphoe exceedingly hilly, cultivated; but bare stone walls, or mounds of earth, forming the enclosures.

From Raphoe to Derry, for the first seven or eight miles, nothing worthy of observation. Great hills without rocks, enclosed, and gentle in their declivities.

Within four miles of Derry, a view of the Foyle, a great river; here, indeed, an arm of the sea, affected by the tides: near Derry the banks wooded, and the whole landlocked; the hills of Donegal and the cliffs of Macgilligan in the back-ground. Derry a well-built and lively city; much business done, but I should conceive too remote from the main ocean to admit of a quick navigation to the ports of the north of England or Scotland, and not likely to rival Belfast.

From Derry to Newtown Limavaddy, the first four miles through a flat cultivated country, backed by the hills of Donegal, bounding Loch Foyle; gradually scenes of beauty appear, fine woods on the banks of the sea; Scotch firs in abundance, birch, oak, holly. The distances very grand. The blue face of Loch Foyle, bounded to the west by the grey misty land of Donegal, and to the east by the grand and elevated cliffs of Macgilligan, the bases of which smile with verdure and cultivation, and the summits of which abrupt crags frown barren, desolate, and exposed to all the storms of the north. Newtown Limavaddy beautifully situated on the banks of a little clear meandering river, and elevated upon a gentle hill: a plain beneath, with meads and light and beautiful woods; the near hills wooded, and mountains, with green sides and bare summits, in the eastern distance. The amphitheatre of mountains all of peculiar characters, and the character of the eastern chain marking a new country; a long line of ascent from the north, and a rapid declivity towards the south.

2. The micaceous schist extends on the banks of the river of Newtown Limavaddy, having similar characters to those which it possesses in Donegal. Here, at Newtown Limavaddy, rises the great basaltic cliff

of Renavenac. No point of junction of this district with the schistose district appears. The summit of Renavenac is composed of a number of layers of basalt, rude in their forms, and grand in their outlines. Below the face of the cliff are irregular crags, containing an immense number of zeolites; zeolites, agate, and calcareous spars are found in all the cavities of the basalt. The cliff can scarcely be less than 2000 feet above the level of the sea, and is exceedingly difficult of access. Small seams of coal are said to have been found at the base. A quarry of white limestone, with flints, has been broken in upon, and some scattered fragments of occur on both sides. The first regular exposed superposition of basalt, with regard to chalk, is to be found at a cliff about three miles to the north. This chalk is of the same degree of consolidation as the lias limestone. Layers of single flints unaltered occur within six feet of it, and are seldom altered within two feet. These layers of flints are usually about two feet or twenty-eight inches asunder, and are usually about twice the size of the fist. The chalk stratum appears here at about thirty feet in height, and is topped by basalt, from three to four hundred feet probably. Immediately above the chalk is a great layer of flint, four feet in thickness, with a red intermediate substance. Here the flints are either reddened, white, or crumbly in some of their parts, and the basalt at the point of contact is very decomposable.

The stratification of these cliffs is well marked. In one part these strata were distinct:—

1. Irregular columnar basalt.
2. Small tabular schistose decomposing basalt.
3. Tabular basalt.
4. An ochreous stratum of small thickness.

5. Irregular tabular basalt, coming upon the flint in irregular outline.

6. The flints generally red or white, and much fractured, with a soft ochreous substance between them.

7. The chalk with its strata of flints declining towards the east, and lost about a mile off. The basalt likewise becomes lower towards the east, and the whole declination seems to be of this side.

[Here may be introduced the author's sentiments relative to the natural advantages of Ireland, and its capacity for improvement, physically considered;—they were expressed in a lecture introductory to a course on electro-chemical science, which he delivered at the Dublin Society in 1811; and arose out of reflections on the influence of science on the best interests of a country.]

Every part of the British dominions is interested in the progress of experimental science; but no part ought to be in so high a degree interested as this island (Ireland.) Its natural advantages are pre-eminent. It contains an untouched fund of wealth, admirably situated for commercial intercourse with the whole world; intersected by navigable rivers and lakes; supplied abundantly with fuel,—possessing limestone prepared for the fire in every district—abounding in mineral treasures,—coal and iron below; and an inexhaustible source of manure upon the surface,—it needs only an enterprising spirit, directed by science, calling forth and awakening the industry of the people, to render it, in proportion to its extent, the most productive, the richest part of the empire.

[His views relative to the political state of Ireland, founded on his own observations, are briefly and

forcibly expressed in a letter to his friend, Mr. Poole.]

I long very much for the intercourse of a week with you: I have very much to say about Ireland. It is an island which might be made a new and a great country. It now boasts a fertile soil, an ingenious and robust peasantry, and a rich aristocracy; but the bane of the nation, is the equality of poverty amongst the lower orders. All are slaves, without the probability of becoming free; they are in the state of equality which the *sans culottes* wished for in France; and, until emulation and riches, and the love of clothes and neat houses are introduced amongst them, there will be no permanent improvement.

Changes in political institutions can, at first, do little towards serving them: it must be by altering their habits, by diffusing manufactories, by destroying *middle men*, by dividing farms, and by promoting industry, by making the pay proportional to the work: but I ought not to attempt to say anything on the subject, when my limits are so narrow; I hope soon to converse with you about it.

[Another letter to the same gentleman, in part applicable to the state of Ireland, may be deserving of a place here.]

To Thomas Poole, Esq.

My dear Poole,

What you have written concerning the indifference of men with regard to the interest of the species in future ages, is perfectly just and philosophical; but the greatest misfortune is, that men do not attend even to their own interest, and to the interest of their own age, in public matters. They think in moments, instead of thinking,

as they ought to do, in years; and they are guided by expediency, rather than by reason. The true political maxim is, that the good of the whole community, is the good of every individual; but how few statesmen have ever been guided by this principle! In almost all governments the plan has been to sacrifice one part of the community to other parts; sometimes the people to the aristocracy; at other times, the aristocracy to the people; sometimes the colonies to the mother country; and at other times, the mother country to the colonies. A generous, enlightened policy, has never existed in Europe, since the days of Alfred; and what has been called 'the balance of power,' the support of civilization, has been produced only by jealousy, envy, bitterness, contest, and eternal war, either carried on by pens or cannon, destroying men morally and physically! But if I proceed in vague political declamation, I shall have no room left for the main object of my letter—your mine. I wish it had been in my power to write decidedly on the subject; but your county is a peculiar one.* Such indications would be highly favourable in Cornwall; but in a *shell limestone*, of late formation, there have, as yet, been no instances of great copper mines. I hope, however, that your mine will produce a rich store of *facts*.

Miners from Alston Moor, or from Derbyshire, would understand your country better than Cornish miners; for the Cornish shifts are wholly different from yours. It would be well for you to have some workmen at least from the north, as they are well acquainted with *shell limestone*.

The Ecton copper mine, in Staffordshire, is in this rock: it would be right for you to get a plan and his-

* [Somersetshire.]

tory of that mine, which might possibly assist your views.

Had I been rich, I would adventure; but I am just going to embark with all the little money I have been able to save, for a scientific expedition to Norway, Lapland, and Sweden.* In all climes,

I shall be your warm and sincere friend,

H. DAVY.

* [This plan of travel was not carried into effect at the time; but was in part realized many years after, as noticed in the preliminary volume.]

ELEMENTS

OF

AGRICULTURAL CHEMISTRY,

IN

A COURSE OF LECTURES

FOR

THE BOARD OF AGRICULTURE;

DELIVERED BETWEEN 1802 AND 1812.

[To Messrs. Longmans and Co., the proprietors of the copyright of the Lectures on Agricultural Chemistry, the Editor has to express his thanks for the liberality with which they have permitted him to include them in this collection. The fourth edition of the work is that which has been selected to be printed from, having had the last revision of the author.

The dedication given, is from the same edition; the first was inscribed to the President and Members of the Board of Agriculture for the year 1812, at whose request the Lectures were first published "as a testimony of the respect of the author, and of gratitude for the attention with which they have been received." The last was prompted by private feelings of regard and respect to a distinguished individual, between whom and the author for many years a friendship was maintained without interruption, of that best kind, equally valued by both. Mr. Knight has given expression to his sentiments towards the author, in a passage written in the most amiable and friendly manner, which has been introduced in the first volume. The author's towards Mr. Knight are not less forcibly pourtrayed in the letters which from time to time he wrote to him, during a period of at least twenty years. For the perusal of these, and for copies, the editor is indebted to the considerate kindness of Mrs. Stackhouse Acton, from whom he is glad to learn that some of these letters are to be inserted in a memoir of the life of her late father, now preparing for publication. Had the editor seen them before, and in time, he would have considered it a duty to have inserted a selection from them, as they are very illustrative: at present he restricts himself to one, written after a very distressing event, the sudden death, from an accident, of Mr. Knight's only son, in the prime of manhood, full of promise of excellence (alluded to in the first volume in page 463), depicting equally the strong emotions of grief and of the sympathy of the writer.]

To Thomas Andrew Knight, Esq.

January 17*th*, 1827.

My Dear Sir,

I have three or four times within the last six weeks taken up the pen and begun to write to you; but I have always laid it down again, fearing

to trust myself with a subject on which I could not write without feeling deeply, and great mental agitation.

I have grieved with you: in such the most awful visitation of evil belonging to human nature, it is almost vain to attempt to offer consolation; yet considering life as a great system in which all is for good; and believing that the intellectual and moral part of our nature is as indestructible as the atoms that compose our frames, I feel the conviction that when a mind so highly gifted and so little selfish is removed from this scene of being, apparently so prematurely, it is to act in a better and nobler state of existence. The noblest spirits often return soonest to the source of intellectual life from which they sprung; and they are surely the happiest; whilst we are to await the trials of sorrow, sickness, and age.

I was very grateful to your most amiable and angelic daughter, Mrs. Stackhouse, for a note that she wrote to me. Pray offer her my most sincere thanks.

I offer my most ardent wishes for your recovery and that of Mrs. Knight. I know well the agony of "*spes fracta*;" but even in this case, time, the chief comforter, creates a new source of hope.

I wish I could give you a more satisfactory answer to your kind inquiries respecting my health. Dr. Philip has been very kind to me, "but my body does me sorely wrong." I sometimes hope and sometimes despair of ultimate recovery. My paralytic symptoms are much diminished; but still I cannot get rid of the stiffness in my left arm and leg. I am now amusing myself with inquiries in natural history, and I hope in the spring to make some inquiries respecting the transmigrations of some of the angler's water-flies.

The garden of the Zoological Society is flourishing, and there are a good many animals collected there.

The political bark left by Mr. Canning without a pilot seems quite wrecked; and I believe there will be some difficulty in building another. The country is in a very critical state, and there certainly never was a moment in which less political talent appeared; but I am writing on a subject which every body seems alike ignorant of, and the business is, I fear, in hands weak in talent though strong in influence,

I am, my dear sir, very sincerely,

Your obliged friend,

H. DAVY.

TO

THOMAS ANDREW KNIGHT, ESQ., F.R.S.,

PRESIDENT OF THE HORTICULTURAL SOCIETY,

THIS EDITION OF THESE LECTURES

IS INSCRIBED

BY HIS FRIEND,

THE AUTHOR.

ADVERTISEMENT TO THE FOURTH EDITION.

During ten years, from 1802 to 1812, I had the honour, every Session, of delivering Courses of Lectures before the Board of Agriculture. I endeavoured, at all times, to follow in them the progress of discovery; they, therefore, varied every year: and since they were first published, in 1813, some considerable improvements have been made in chemical science, which have rendered many alterations and additions necessary.

I am indebted for much useful information to many gentlemen who have endeavoured to improve agriculture, and to apply scientific principles to this most important of the arts; of which, acknowledgments will be found in the body of the work. I hope there are no omissions on this head; but should they exist, I trust they will be attributed to defect of recollection, and not to any want of candour or of gratitude.

Where I have derived any specific statement from books, I have always quoted them; but I have not always made references to such doctrines as are become current, the authors of which are well known; and which may be almost considered as the property of all enlightened minds.

In revising this work for the fourth edition, I have been forcibly struck with its imperfections, and I regret that I have been able to do so little to render it more worthy of the approbation of those readers for whom it

was designed. My object has been principally to dwell upon practical principles and practical applications of science; and it is in the farm and not in the laboratory that these can be put to the test of experiment, and my duties and pursuits have rendered it impossible for me to do more than point out the path of inquiry—to indicate the road to improvement. The manner in which the work has been received, both in this country and the Continent, induces me to hope that its object, however humble, has been to a certain extent attained, and that it has not been without its utility.

I have retained an appendix containing an account of the experiments on grasses instituted by the Duke of Bedford at Woburn, because many of these experiments are alluded to in the body of the work. I am happy, however, to be able to refer my readers to a much fuller and more detailed account of this subject of investigation, in a treatise published by Mr. George Sinclair, entitled *Hort. Gram. Woburnensis*, and which, from the nature of the details, and the singular modesty and clearness with which they are given, is well worthy the perusal of all persons interested in agricultural pursuits.

H. Davy.

Park Street, Jan. 1, 1827.

ELEMENTS OF AGRICULTURAL CHEMISTRY.

LECTURE I.

Introduction.—General Views of the Objects of the Course, and of the Order in which they are to be discussed.

It is with great pleasure that I receive the permission to address so distinguished and enlightened an audience on the subject of agricultural chemistry.

That any thing which I am able to bring forward, should be thought worthy the attention of the Board of Agriculture, I consider as an honour; and I shall endeavour to prove my gratitude, by employing every exertion to illustrate this department of knowledge, and to point out its uses.

In attempting these objects, the peculiar state of the inquiry presents many difficulties to a lecturer. Agricultural chemistry has not yet received a regular and systematic form. It has been pursued by competent experimenters for a short time only: the doctrines have not as yet been collected into any elementary treatise; and on an occasion when I am obliged to trust so much to my own arrangements, and to my own limited information, I cannot but feel diffident as to the interest that may be excited, and doubtful of the success of the undertaking. I know, however, that your candour will induce you not to expect any thing like a finished work upon a science as yet in its infancy; and I am sure you will receive with indulgence the first attempt made in

this country to illustrate it, by a series of experimental demonstrations.

Agricultural chemistry has for its objects all those changes in the arrangements of matter connected with the growth and nourishment of plants; the comparative values of their produce as food; the constitution of soils; the manner in which lands are enriched by manure, or rendered fertile by the different processes of cultivation. Inquiries of such a nature cannot but be interesting and important, both to the theoretical agriculturist, and to the practical farmer. To the first they are necessary in supplying most of the fundamental principles on which the theory of the art depends. To the second they are useful in affording simple and easy experiments for directing his labours, and for enabling him to pursue a certain and systematic plan of improvement.

It is scarcely possible to enter upon any investigation in agriculture without finding it connected, more or less, with doctrines or elucidations derived from chemistry.

If land be unproductive, and a system of ameliorating it is to be attempted, the sure method of obtaining the object is by determining the cause of its sterility, which must necessarily depend upon some defect in the constitution of the soil, which may be easily discovered by chemical analysis.

Some lands of good apparent texture are yet sterile in a high degree; and common observation and common practice afford no means of ascertaining the cause, or of removing the effect. The application of chemical tests in such cases is obvious; for the soil must contain some noxious principle, which may be easily discovered, and probably easily destroyed.

Are any of the salts of iron present? they may be decomposed by lime. Is there an excess of siliceous sand? the system of improvement must depend on the application of clay and calcareous matter. Is there a defect of calcareous matter? the remedy is obvious. Is an excess of vegetable matter indicated? it may be removed by liming, paring, and burning. Is there a deficiency of vegetable matter? it is to be supplied by manure.

A question concerning the different kinds of limestone to be employed in cultivation often occurs. To determine this fully in the common way of experience, would demand a considerable time, perhaps some years, and trials which might be injurious to crops; but by simple chemical tests the nature of a limestone is discovered in a few minutes; and the fitness of its application, whether as a manure for different soils, or as a cement, determined.

Peat earth of a certain consistence and composition is an excellent manure; but there are some varieties of peats which contain so large a quantity of ferruginous matter as to be absolutely poisonous to plants. Nothing can be more simple than the chemical operation for determining the nature, and the probable uses of a substance of this kind.

There has been no question on which more difference of opinion has existed, than that of the state in which manure ought to be ploughed into the land; whether recent, or when it has gone through the process of fermentation? and this question is still a subject of discussion: but whoever will refer to the simplest principles of chemistry, cannot entertain a doubt on the subject. As soon as dung begins to decompose, it throws off its volatile parts, which are the most valuable and

most efficient. Dung which has fermented, so as to become a mere soft cohesive mass, has generally lost from one-third to one-half of its most useful constituent elements; and, that it may exert its full action upon the plant, and lose none of its nutritive powers, it should evidently be applied much sooner, and long before decomposition has arrived at its ultimate results.

It would be easy to adduce a multitude of other instances of the same kind; but sufficient, I trust, has been said to prove, that the connection of chemistry with agriculture, is not founded on mere vague speculation, but that it offers principles which ought to be understood and followed, and which, in their progression and application, can hardly fail to be highly beneficial to the community.

A view of the objects in this course of lectures, and of the manner in which they are to be treated, will not, I hope, be considered as an improper introduction. It will inform you what you are to expect; it will afford a general idea of the connection of the different parts of the subject, and of their relative importance; it will enable me to give some historical details of the progress of this branch of knowledge, and to reason from what has been ascertained, concerning what remains to be investigated and discovered.

The phenomena of vegetation must be considered as an important branch of the science of organized nature; but though exalted above inorganic matter, vegetables are yet in a great measure dependent for their existence upon its laws. They receive their nourishment from the external elements; they assimilate it by means of peculiar organs; and it is by examining their physical and chemical constitution, and the substances and powers which act upon them, and the modifications

which they undergo, that the scientific principles of agricultural chemistry are obtained.

According to these ideas, it is evident that the study ought to be commenced by some general inquiries into the composition and nature of material bodies, and the laws of their changes. The surface of the earth, the atmosphere, and the water deposited from it, must either together or separately afford all the principles concerned in vegetation; and it is only by examining the chemical nature of these principles, that we are capable of discovering what is the food of plants, and the manner in which this food is supplied and prepared for their nourishment. The principles of the constitution of bodies, consequently, will form the first subject for our consideration.

By methods of analysis dependent upon chemical and electrical instruments discovered in late times, it has been ascertained that all the varieties of material substances may be resolved into a comparatively small number of bodies, which, as they are not capable of being decompounded, are considered in the present state of chemical knowledge as elements. The bodies incapable of decomposition at present known are fifty-two.* Of these forty are metals; eight are inflammable bodies; and five are substances which unite with metals and inflammable bodies, and form with them acids, alkalies, earths, or other analogous compounds. The chemical elements acted upon by attractive powers combine in different aggregates. In their simpler combinations, they produce various crystalline substances, distinguished by the regularity of their forms. In more complicated arrangements, they constitute the

* [Now fifty-four; since 1827 two new metals have been discovered, thorium by Berzelius, vanadium by Sefström.]

varieties of vegetable and animal substances, bear the higher character of organization, and are rendered subservient to the purposes of life. And by the influence of heat, light, and electrical powers, there is a constant series of changes; matter assumes new forms, the destruction of one order of beings tends to the conservation of another; solution and consolidation, decay and renovation, are connected; and whilst the parts of the system continue in a state of fluctuation and change, the order and harmony of the whole remain unalterable.

After a general view has been taken of the nature of the elements, and of the principles of chemical changes, the next object will be the structure and constitution of plants. In all plants there exists a system of tubes or vessels, which in one extremity terminate in roots, and at the other in leaves. It is by the capillary action of the roots that fluid matter is taken up from the soil. The sap in passing upwards becomes denser, and more fitted to deposit solid matter: it is modified by exposure to heat, light, and air in the leaves; descends through the bark, in its progress produces new organized matter; and is thus, in its vernal and autumnal flow, the cause of the formation of new parts, and of the more perfect evolution of parts already formed.

In this part of the inquiry, I shall endeavour to connect together into a general view, the observations of the most enlightened philosophers who have studied the physiology of vegetation. Those of Grew, Malpighi, Sennebier, Darwin, De Candolle, Mirbel; and, above all, of Mr. Knight: he is the latest inquirer into these interesting subjects, and his labours have tended most to illustrate this part of the economy of nature.

The chemical composition of plants has, within the last ten years, been elucidated by the experiments of a

number of chemical philosophers, both in this and in other countries; and it forms a beautiful part of general chemistry: it is too extensive to be treated of minutely; but it will be necessary to dwell upon such parts of it, as afford practical inferences.

If the organs of plants be submitted to chemical analysis, it is found that their almost infinite diversity of form depends upon different arrangements and combinations of a very few of the elements; seldom more than seven or eight belong to them, and three constitute the greatest part of their organized matter; and according to the manner in which these elements are disposed, arise the different properties of the products of vegetation, whether employed as food, or for other purposes and wants of life.

The value and uses of every species of agricultural produce are most correctly estimated and applied, when practical knowledge is assisted by principles derived from chemistry. The compounds in vegetables really nutritive as the food of animals, are very few; farina or the pure matter of starch, gluten, sugar, vegetable jelly, oil, and extract. Of these the most nutritive is gluten, which approaches nearest in its nature to animal matter, and which is the substance that gives to wheat its superiority over other grain. The next in order as to nourishing power is oil, then sugar, then farina; and last of all, gelatinous and extractive matters. Simple tests of the relative nourishing powers of the different species of food, are the relative quantities of these substances that they afford by analysis; and though taste and appearance must influence the consumption of all articles in years of plenty, yet they are less attended to in times of scarcity, and on such occasions this kind of knowledge may be of the greatest importance.

Sugar and farina, or starch, are very similar in composition, and are capable of being converted into each other by simple chemical processes. In the discussion of their relations, I shall detail to you the results of some recent experiments, which will be found possessed of applications both to the economy of vegetation, and to some important processes of manufacture.

All the varieties of substances found in plants, are produced from the sap; and the sap of plants is derived from water, or from the fluids of the soil, and it is altered by, or combined with, principles derived from the atmosphere. The influence of the soil, of water, and of air, will therefore be the next subject of consideration. Soils in all cases consist of a mixture of different finely divided earthy matters; with animal or vegetable substances in a state of decomposition, and certain saline ingredients. The earthy matters are the true basis of the soil; the other parts, whether natural, or artificially introduced, operate in the same manner as manures. Four earths generally abound in soils; the aluminous, the siliceous, the calcareous, and the magnesian. These earths, as I have discovered, consist of highly inflammable metals, united to pure air or oxygen; and they are not, as far as we know, decomposed or altered in vegetation.

The great use of the soil is to afford support to the plant, to enable it to fix its roots, and to derive nourishment by its tubes slowly and gradually, from the soluble and dissolved substances mixed with the earths.

That a particular mixture of the earths is connected with fertility, cannot be doubted: and almost all sterile soils are capable of being improved, by a modification of their earthy constituent parts. I shall describe the simplest method as yet discovered of analysing soils,

and of ascertaining the constitution and chemical ingredients which appear to be connected with fertility; and on this subject many of the former difficulties of investigation will be found to be removed by recent inquiries.

The necessity of water to vegetation, and the luxuriancy of the growth of plants connected with the presence of moisture in the southern countries of the old continent, led to the opinion so prevalent in the early schools of philosophy, that water was the great productive element, the substance from which all things were capable of being composed, and into which they were finally resolved. The "αριστον μεν ὑδωρ" of the poet, "water is the noblest," seems to have been an expression of this opinion, adopted by the Greeks from the Egyptians, taught by Thales, and revived by the alchemists in late times. Van Helmont, in 1610, conceived that he had proved, by a decisive experiment, that all the products of vegetables were capable of being generated from water. His results were shown to be fallacious by Woodward in 1691; but the true use of water in vegetation was unknown till 1785; when Mr. Cavendish made the discovery, that it was composed of two elastic fluids or gases, inflammable gas or hydrogen, and vital gas or oxygen.

Air, like water, was regarded as a pure element by most of the ancient philosophers; a few of the chemical inquirers in the sixteenth and seventeenth centuries, formed some happy conjectures respecting its real nature. Sir Kenelm Digby, in 1660, supposed that it contained some saline matter, which was an essential food of plants. Boyle, Hook, and Mayow, between 1665 and 1680, stated, that a small part of it only was consumed in the respiration of animals, and in the

combustion of inflammable bodies; but the true statical analysis of the atmosphere is comparatively a recent labour, achieved towards the end of the last century by Scheele, Priestley, and Lavoisier. These celebrated men showed that its principal elements are two gases, oxygen and azote, of which the first is essential to flame, and to the life of animals, and that it likewise contains small quantities of aqueous vapour, and of carbonic acid gas; and Lavoisier proved that this last body is itself a compound elastic fluid, consisting of charcoal dissolved in oxygen.

Jethro Tull, in his treatise on Horse-hoeing, published in 1733, advanced the opinion, that minute earthy particles supplied the whole nourishment of the vegetable world; that air and water were chiefly useful in producing these particles from the land; and that manures acted in no other way than in ameliorating the texture of the soil, in short, that their agency was mechanical. This ingenious author of the new system of agriculture having observed the excellent effects produced in farming, by a minute division of the soil, and the pulverization of it by exposure to dew and air, was misled, by carrying his principles too far. Duhamel, in a work printed in 1754, adopted the opinion of Tull, and stated, that, by finely dividing the soil, any number of crops might be raised in succession from the same land. He attempted also to prove, by direct experiments, that vegetables of every kind were capable of being raised without manure. This celebrated horticulturist lived, however, sufficiently long to alter his opinion. The results of his later and most refined observations led him to the conclusion, that no single material afforded the food of plants. The general experience of farmers had long before convinced the unprejudiced

of the truth of the same opinion, and that manures were absolutely consumed in the process of vegetation. The exhaustion of soils, by carrying off corn crops from them, and the effects of feeding cattle on lands, and of preserving their manure, offer familiar illustrations of the principle; and several philosophical inquirers, particularly Hassenfratz and Saussure, have shown, by satisfactory experiments, that animal and vegetable matters deposited in soils are absorbed by plants, and become a part of their organized matter. But though neither water, nor air, nor earth, supplies the whole of the food of plants, yet they all operate in the process of vegetation. The soil is the laboratory in which the food is prepared. No manure can be taken up by the roots of plants, unless water is present; and water, or its elements, exist in all the products of vegetation. The germination of seeds does not take place without the presence of air or oxygen gas: and in the sunshine, vegetables decompose the carbonic acid gas of the atmosphere, the carbon of which is absorbed, and becomes a part of their organized matter, and the oxygen gas, the other constituent, is given off; and, in consequence of a variety of agencies, the economy of vegetation is made subservient to the general order of the system of nature.

It is shown, by various researches, that the constitution of the atmosphere has been always the same since the time that it was first accurately analysed; and this must, in a great measure, depend upon the powers of plants to absorb or decompose the putrifying or decaying remains of animals and vegetables and the gaseous effluvia which they are constantly emitting. Carbonic acid gas is formed in a variety of processes of fermentation and combustion, and in the respiration of animals; and as yet no other process is known in nature by which

it can be consumed, except vegetation. Animals produce a substance which appears to be a necessary food of vegetables; vegetables evolve a principle necessary to the existence of animals; and these different classes of beings seem to be thus connected together in the exercise of their living functions, and to a certain extent made to depend upon each other for their existence. Water is raised from the ocean, diffused through the air, and poured down upon the soil, so as to be applied to the purposes of life. The different parts of the atmosphere are mingled together by winds or changes of temperature, and successively brought in contact with the surface of the earth, so as to exert their fertilizing influence. The modifications of the soil, and the application of manures, are placed within the power of man, as if for the purpose of awakening his industry, and of calling forth his powers.

The theory of the general operation of the more compound manures, may be rendered very obvious, by simple chemical principles; but there is still much to be discovered, with regard to the best methods of rendering animal and vegetable substances soluble; with respect to the processes of decomposition, how they may be accelerated or retarded, and the means of producing the greatest effects from the materials employed; these subjects will be attended to in the Lectures on Manures.

Plants are found by analysis to consist principally of charcoal and aëriform matter. They give out, by distillation, volatile compounds; the elements of which are pure air, inflammable air, coally matter, and azote, or that elastic substance which forms a great part of the atmosphere, and which is incapable of supporting combustion. These elements they gain, either by their

leaves from the air, or by their roots from the soil. All manures from organized substances, contain the principles of vegetable matter, which, during putrefaction, are rendered either soluble in water or aëriform—and in these states they are capable of being assimilated to the vegetable organs. No one principle affords the pabulum of vegetable life; it is neither charcoal, nor hydrogen, nor azote, nor oxygen alone; but all of them together, in various states and various combinations. Organic substances, as soon as they are deprived of vitality, begin to pass through a series of changes, which ends in their complete destruction, in the entire separation and dissipation of the parts. Animal matters are the soonest destroyed by the operation of air, heat, and light. Vegetable substances yield more slowly, but finally obey the same laws. The periods of the application of manures from decomposing animal and vegetable substances, depend upon the knowledge of these principles; and I shall be able to produce some new and important facts founded upon them, which, I trust, will remove all doubt from this part of agricultural theory.

The chemistry of the more simple manures, the manures which act in very small quantities, such as gypsum, alkalies, and various saline substances, has hitherto been exceedingly obscure. It has been generally supposed that these materials act in the vegetable economy, in the same manner as condiments or stimulants in the animal economy, and that they render the common food more nutritive. It seems, however, a much more probable idea, that they are actually a part of the true food of plants, and that they supply that kind of matter to the vegetable fibre, which is analogous to the bony matter in animal structures.

The operation of gypsum, it is well known, is extremely capricious in this country, and no certain data have hitherto been offered for its application.

There is, however, good ground for supposing that the subject will be fully elucidated by chemical inquiry. Those plants which seem most benefited by its application, are plants which always afford it on analysis. Clover, and most of the artificial grasses, contain it; but it exists in very minute quantity only in barley, wheat, and turnips. Many peat ashes, which are sold at a considerable price, consist in great part of gypsum, with a little iron; and the first seems to be their most active ingredient. I have examined several of the soils to which these ashes are successfully applied, and I have found in them no sensible quantity of gypsum. In general, cultivated soils contain sufficient of this substance for the use of the grasses; in such cases, its application cannot be advantageous. For plants require only a certain quantity of manure; an excess may be detrimental, and cannot be useful.

The theory of the operation of alkaline substances, is one of the parts of the chemistry of agriculture most simple and distinct. They are found in all plants, and therefore may be regarded as amongst their essential ingredients. From their powers of combination, likewise, they may be useful in introducing various principles into the sap of vegetables, which may be subservient to their nourishment.

The fixed alkalies, which were formerly regarded as elementary bodies, it has been my good fortune to decompose. They consist of pure air, united to highly inflammable metallic substances; but there is no reason to suppose that they are reduced into their elements in any of the processes of vegetation.

In this part of the course, I shall dwell at considerable length on the important subject of lime, and I shall be able to offer some novel views.

Slacked lime was used by the Romans for manuring the soil in which fruit-trees grew; of this we are informed by Pliny. Marl had been employed by the Britons and the Gauls, from the earliest times, as a top-dressing for land. But the precise period in which burnt lime first came into general use in the cultivation of land, is, I believe, unknown. The origin of the application from the early practices, is sufficiently obvious; a substance which had been used with success in gardening, must have been soon tried in farming; and in countries where marl was not to be found, calcined limestone would be naturally employed as a substitute.

The elder writers on agriculture, had no correct notions of the nature of lime, limestone, and marl, or of their effects; and this was the necessary consequence of the imperfection of the chemistry of the age. Calcareous matter was considered by the alchemists as a peculiar earth, which, in the fire, became combined with inflammable acid; and Evelyn and Hartlib,—and, still later, Lisle, in their works on husbandry, have characterised it merely as a hot manure of use in cold lands. It is to Dr. Black, of Edinburgh, that our first distinct rudiments of knowledge on the subject are owing. About the year 1755, this celebrated professor proved, by the most decisive experiments, that limestone and all its modifications, marbles, chalks, and marls, consist principally of a peculiar earth united to an aërial acid: that the acid is given out in burning, occasioning a loss of more than 40 per cent.; and that the lime in consequence becomes caustic.

These important facts immediately applied, with

equal certainty, to the explanation of the uses of lime, both as a cement and as a manure. As a cement, lime, applied in its caustic state, acquires its hardness and durability, by absorbing the aërial (or, as it has been since called, carbonic) acid, which always exists in small quantities in the atmosphere; it becomes, as it were, again limestone.

Chalks, calcareous marls, or powdered limestones, act merely by forming an useful earthy ingredient of the soil; and their efficacy is proportioned to the deficiency of calcareous matter, which, in larger or smaller quantities, seems to be an essential ingredient of all fertile soils; necessary, perhaps, to their proper texture, and as an ingredient in the organs of plants.

Burnt lime, in its first effect, acts as a decomposing agent upon animal or vegetable matter, and seems to bring it into a state in which it becomes more rapidly a vegetable nourishment;* gradually, however, the lime is neutralised by carbonic acid, and converted into a substance analogous to chalk; but in this case it more perfectly mixes with the other ingredients of the soil, is more generally diffused and finely divided; and it is probably more useful to land than any calcareous substance in its natural state.

The most considerable fact made known, with regard to limestone, within the last few years, is owing to Mr. Tennant. It had been long known, that a particular species of limestone, found in different parts of the North of England, when applied in its burnt and

* [This effect is questionable; from some experiments which I have instituted, the results of which are described in the second volume of my Physiological and Anatomical Researches, lime appears to act as an antiseptic on animal and vegetable substances in general, and to preserve them, with the exception of cuticle, which it disorganizes.]

slacked state to land in considerable quantities occasioned sterility, or considerably injured the crops for many years. Mr. Tennant, in 1800, by a chemical examination of this species of limestone, ascertained that it differed from common limestones by containing magnesian earth; and by several experiments he proved, that this earth was prejudicial to vegetation, when applied in large quantities in its caustic state. Under common circumstances, the lime from the magnesian limestone is, however, used in moderate quantities upon fertile soils in Leicestershire, Derbyshire, and Yorkshire, with good effect; and it may be applied in greater quantities to soils containing very large proportions of vegetable matter. Magnesia, when combined with carbonic acid gas, seems not to be prejudicial to vegetation, and in soils rich in manure it is speedily supplied with this principle from the decomposition of the manure.

After the nature and operation of manures have been discussed, the next, and the last subject for our consideration, will be some of the operations of husbandry capable of elucidation by chemical principles.

The chemical theory of fallowing is very simple. Fallowing affords a source of riches to the soil, in consequence of the absorption of oxygen and the aqueous principles of the atmosphere, and so tends to produce an accumulation of decomposing matter, which, in the common course of crops, would be employed as it is formed; yet in highly cultivated soils, under a regular succession of crops, properly manured, this practice can rarelybe advantageous; and the cases in which it is really beneficial are for the destruction of weeds, and for cleansing foul soils.

The chemical theory of paring and burning, I shall discuss fully in this part of the Course.

It is obvious, that in all cases it must destroy a certain quantity of vegetable matter, and must be principally useful in cases in which there is an excess of this matter in soils. Burning, likewise, renders clays less coherent, and in this way greatly improves their texture, and causes them to be less permeable to water.

The instances in which it must be obviously prejudicial are those of sandy dry siliceous soils, containing little animal or vegetable matter. Here it can only be destructive, for it decomposes that on which the soil depends for its productiveness.

The advantages of irrigation, though so lately a subject of much attention, were well known to the ancients; and more than two centuries ago the practice was recommended to the farmers of our country by Lord Bacon: "Meadow-watering," according to the statements of this illustrious personage (given in his Natural History, in the article Vegetation,) "acts not only by supplying useful moisture to the grass; but likewise the water carries nourishment dissolved in it, and defends the roots from the effects of cold."

No general principles can be laid down respecting the comparative merit of the different systems of cultivation and the various systems of crops adopted in different districts, unless the chemical nature of the soil, and the physical circumstances to which it is exposed, are fully known. Stiff coherent soils are those most benefited by minute division and aëration, and in the drill system of husbandry these effects are produced to the greatest extent; but still the labour and expense connected with its application in certain districts may not be compensated for by the advantages produced,

and there are some stiff soils which must be left in clods when sown with wheat. Moist climates are best fitted for raising the artificial grasses, oats, and broad-leaved crops; stiff aluminous soils, in general, are most adapted for wheat crops; and calcareous soils produce excellent sainfoin and clover.

Nothing is more wanting in agriculture than experiments in which all the circumstances are minutely and scientifically detailed. This art will advance with rapidity in proportion as it becomes exact in its methods. As in physical researches, all the causes should be considered; a difference in the results may be produced, even by the fall of a half inch of rain more or less in the course of a season, or a few degrees of temperature, or even by a slight difference in the sub-soil, or in the inclination of the land.

Information collected after views of distinct inquiry would necessarily be fitted for inductive reasoning, and capable of being connected with the general principles of science; and a few histories of the results of truly philosophical experiments in agricultural chemistry would be of more value in enlightening and benefiting the farmer, than the greatest possible accumulation of imperfect trials, conducted merely in the empirical spirit. It is no unusual occurrence for persons who argue in favour of practice and experience to condemn generally all attempts to improve agriculture by philosophical inquiries and chemical methods. That much vague speculation may be found in the works of those who have lightly taken up agricultural chemistry, it is impossible to deny. It is not uncommon to find a number of changes rung upon a string of technical terms, such as oxygen, hydrogen, carbon, and azote, as if the science depended upon words rather than upon

things. But this is, in fact, an argument for the necessity of the establishment of just principles of chemistry on the subject. Whoever reasons upon agriculture, is obliged to recur to this science. He feels that it is scarcely possible to advance a step without it; and if he is satisfied with insufficient views, it is not because he prefers them to accurate knowledge, but generally because they are more current. If a person journeying in the night wishes to avoid being led astray by the ignis fatuus, the most secure method is to carry a lamp in his own hand.

It has been said, and undoubtedly with great truth, that a philosophical chemist would most probably make a very unprofitable business of farming; and this certainly would be the case, if he were a mere philosophical chemist; and unless he had served his apprenticeship to the practice of the art as well as to the theory. But there is reason to believe that he would be a more successful agriculturist than a person equally uninitiated in farming, but ignorant of chemistry altogether; his science, as far as it went, would be useful to him. But chemistry is not the only kind of knowledge required; it forms a small part of the philosophical basis of agriculture; but it is an important part, and whenever applied in a proper manner, must produce advantages.

In proportion as science advances, all the principles become less complicated, and consequently more useful. And it is then that their application is most advantageously made to the arts. The common labourer can never be enlightened by the general doctrines of philosophy, but he will not refuse to adopt any practice, of the utility of which he is fully convinced, because it has been founded upon these principles. The mariner can trust to the compass, though he may be wholly unac-

quainted with the discoveries of Gilbert on magnetism, or the refined principles of that science, developed by the genius of Æpinus. The dyer will use his bleaching liquor, even though he is perhaps ignorant not only of the constitution, but even of the name of the substance on which its powers depend. The great purpose of chemical investigation in agriculture ought undoubtedly to be, the discovery of improved methods of cultivation. But to this end general scientific principles and practical knowledge are alike necessary. The germs of discovery are often found in rational speculations; and industry is never so efficacious as when assisted by science.

It is from the higher classes of the community, from the proprietors of land,—those who are fitted by their education to form enlightened plans, and, by their fortunes, to carry such plans into execution: it is from these that the principles of improvement must flow to the labouring classes of the community; and in all classes the benefit is mutual; for the interest of the tenantry must be always likewise the interest of the proprietors of the soil. The attention of the labourer will be more minute, and he will exert himself more for improvement, when he is certain he cannot deceive his employer, and has a conviction of the extent of his knowledge. Ignorance in the possessor of an estate, of the manner in which it ought to be treated, generally leads either to inattention or injudicious practices in the tenant or the bailiff. "*Agrum pessimum mulctari cujus Dominus non docet sed audit villicum.*"

There is no idea more unfounded than that a great devotion of time, and a minute knowledge of general chemistry, is necessary for pursuing experiments on the nature of soils or the properties of manures. Nothing

can be more easy than to discover whether a soil effervesces, or changes colour by the action of an acid, or whether it burns when heated, or what weight it loses by heat; and yet these simple indications may be of great importance in a system of cultivation. The expense connected with chemical inquiries is extremely trifling; a small closet is sufficient for containing all the materials required. The most important experiments may be made by means of a small portable apparatus; a few phials, containing acids, alkalies, and chemical re-agents; some foil and wire of platinum; a lamp; a crucible; some filtrating paper; some funnels and glasses, for receiving products;—are all that can be considered as absolutely essential for pursuing useful researches.

It undoubtedly happens in agricultural chemical experiments, conducted after the most refined theoretical views, that there are many instances of failure for one of success; and this is inevitable, from the capricious and uncertain nature of the causes that operate, and from the impossibility of calculating on all the circumstances that may interfere: but this is far from proving the inutility of such trials; one happy result, which can generally improve the methods of cultivation, is worth the labour of a whole life; and an unsuccessful experiment, well observed, must establish some truth, or tend to remove some prejudice.

Even considered merely as a philosophical science, this department of knowledge is highly worthy of cultivation. For what can be more delightful than to trace the forms of living beings, and their adaptations and peculiar purposes; to examine the progress of inorganic matter in its different processes of change, till it attain

its ultimate and highest destination,—its subserviency to the purposes of man?

Many of the sciences are ardently pursued, and considered as proper objects of study for all refined minds, merely on account of the intellectual pleasure they afford; merely because they enlarge our views of nature, and enable us to think more correctly with respect to the beings and objects surrounding us. How much more, then, is this department of inquiry worthy of attention, in which the pleasure resulting from the love of truth and of knowledge is as great as in any other branch of philosophy, and in which it is likewise connected with much greater practical benefits and advantages? "*Nihil est melius, nihil uberius, nihil homine libero dignius.*"

Discoveries made in the cultivation of the earth are not merely for the time and country in which they are developed, but they may be considered as extending to future ages, and as ultimately tending to benefit the whole human race; as affording subsistence for generations yet to come; as multiplying life; and not only multiplying life, but likewise providing for its enjoyment.

LECTURE II.

Of the General Powers of Matter which influence Vegetation; of Gravitation, of Cohesion, of Chemical Attraction, of Heat, of Light, of Electricity; Ponderable Substances; Elements of Matter, particularly those found in Vegetables; Laws of their Combinations and Arrangements.

THE great operations of the farmer are directed towards the production or improvement of certain classes of vegetables; they are either mechanical or chemical, and are, consequently, dependent upon the laws which govern common matter. Plants themselves are, to a certain extent, submitted to these laws; and it is necessary to study their effects, both in considering the phenomena of vegetation, and the cultivation of the vegetable kingdom.

One of the most important properties belonging to matter is *gravitation*, or the power by which masses of matter are attracted towards each other. It is in consequence of gravitation that bodies thrown into the atmosphere fall to the surface of the earth, and that the different parts of the globe are preserved in their proper positions. Gravity is exerted in proportion to the quantity of matter. Hence all bodies placed above the surface of the earth fall to it in right lines, which, if produced, would pass through its centre; and a body falling near a high mountain is a little bent out of the perpendicular direction by the attraction of the mountain, as has been shown by the experiments of Dr. Maskelyne on Schehallien.

Gravitation has a very important influence on the growth of plants; and it is rendered probable, by the experiments of Mr. Knight, that they owe the peculiar direction of their roots and branches almost entirely to this force.

That gentleman fixed some seeds of the garden bean on the circumference of a wheel, which in one instance was placed vertically, and in the other horizontally, and made to revolve, by means of another wheel worked by water, in such a manner, that the number of the revolutions could be regulated; the beans were supplied with moisture, and were placed under circumstances favourable to germination. The beans all grew, notwithstanding the violence of revolution, which was sometimes as much as 250 revolutions in a minute on the vertical wheel, which always revolved rapidly, and with little variation of velocity; the radicles, or roots, pointed precisely in the direction of radii in whatever direction they were first placed. The germs took precisely the opposite direction, and pointed to the centre of the wheel, where they soon met each other. Upon the horizontal wheel, the conflicting operation of gravitation and centrifugal force occasioned the germs to form a cone, more or less obtuse, according to the velocity of the wheel, the radicles always taking a course diametrically opposite to that taken by the germs, and, consequently, pointing as much below as the germs pointed above the plane of the wheel's motion.

These facts afford a rational solution of this curious problem, respecting which different philosophers have given such different opinions; some referring it to the nature of the sap, as De la Hire; others, as Darwin, to the living powers of the plant, and the stimulus of

air upon the leaves, and of moisture upon the roots. The effect is now shown to be connected with mechanical causes; and there seems no other power in nature to which it can with propriety be referred, but gravity, which acts universally, and which must tend to dispose the parts to take a uniform direction.*

If plants in general owe their perpendicular direction to gravity, it is evident that the number of plants upon a given part of the earth's circumference cannot be increased by making the surface irregular, as some persons have supposed. Nor can more stalks rise on a hill than on a spot equal to its base; for the slight effect of the attraction of the hill, would be only to make the plants deviate a very little from the perpendicular. Where horizontal layers are pushed forth, as in certain grasses, particularly such as the fiorin, lately brought into notice by Dr. Richardson, more food may, however, be produced upon an irregular surface; but the principle seems to apply strictly to corn crops.

The direction of the radicles and germens is such, that both are supplied with food, and acted upon by those external agents which are necessary for their development and growth. The roots come in contact with the fluids in the ground; the leaves are exposed to light and air; and the same grand law which preserves the planets in their orbits is thus essential to the functions of vegetable life.

When two pieces of polished glass are pressed together they adhere to each other, and it requires

* Fig. 1. represents the case in which the horizontal wheel performed 250 revolutions.

Fig. 2. represents the form of the experiment when the vertical wheel was made to perform 150 revolutions in a minute.

Fig 1.

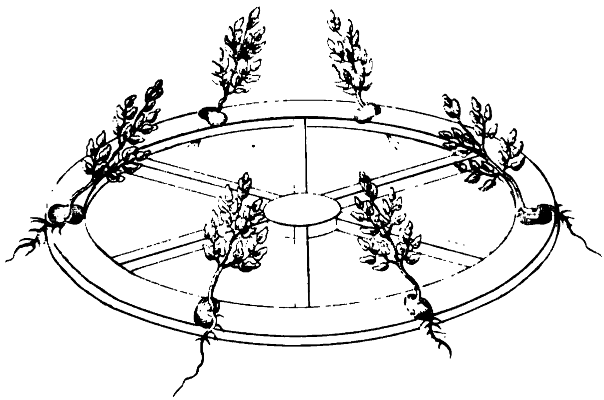
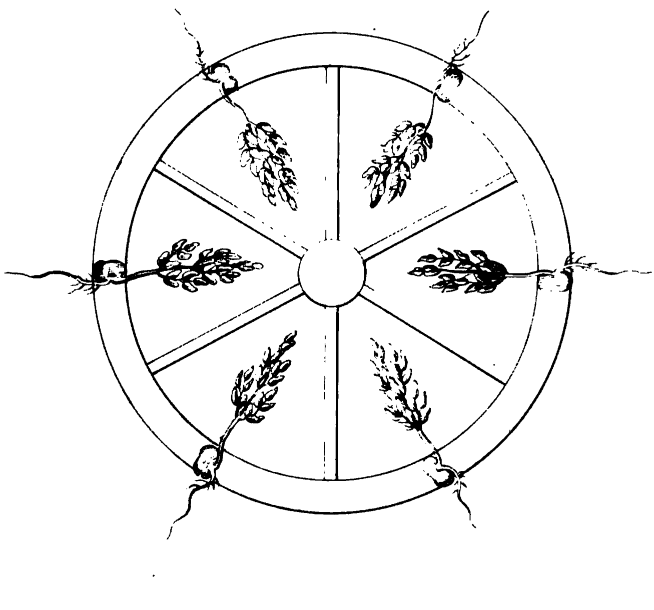


Fig 2.



some force to separate them. This is said to depend upon the *attraction of cohesion.* The same attraction gives the globular form to drops of water, and enables fluids to rise in capillary tubes; and hence it is sometimes called *capillary attraction.* This attraction, like gravitation, seems common to all matter, and may be a modification of the same general force; like gravitation, it is of great importance in vegetation. It preserves the forms of aggregation of the parts of plants, and it seems to be a principal cause of the absorption of fluids by their roots.

If some pure magnesia, the calcined magnesia of druggists, be thrown into distilled vinegar, it gradually dissolves. This is said to be owing to *chemical attraction,* the power by which different species of matter tend to unite into one compound. Various kinds of matter unite with different degrees of force: thus sulphuric acid and magnesia unite with more readiness than distilled vinegar and magnesia; and if sulphuric acid be poured into a mixture of vinegar and magnesia, in which the acid properties of the vinegar have been destroyed by the magnesia, the vinegar will be set free, and the sulphuric acid will take its place. This chemical attraction is likewise called *chemical affinity.* It is active in most of the phenomena of vegetation. The sap consists of a number of ingredients, dissolved in water by chemical attraction; and it appears to be in consequence of the operation of this power, that certain principles derived from the sap are united to the vegetable organs. By the laws of chemical attraction, different products of vegetation are changed, and assume new forms: the food of plants is prepared in the soil; vegetable and animal remains are changed by the

action of air and water, and made fluid or aëriform; rocks are broken down and converted into soils; and soils are more finely divided and fitted as receptacles for the roots of plants.

The different powers of attraction tend to preserve the arrangements of matter, or to unite them in new forms. If there were no opposing powers there would soon be a state of perfect quiescence in nature, a kind of eternal sleep in the physical world. Gravitation is continually counteracted by mechanical powers, by projectile motion, or the centrifugal force; and their joint agencies occasion the motion of the heavenly bodies. Cohesion and chemical attraction are opposed by the *repulsive energy* of *heat*, and the harmonious cycle of terrestrial changes is produced by their mutual operations.

Heat is capable of being communicated from one body to other bodies; and its common effect is to expand them, to enlarge them in all their dimensions. This is easily exemplified. A solid cylinder of metal after being heated will not pass through a ring barely sufficient to receive it when cold. When water is heated in a globe of glass having a long slender neck, it rises in the neck; and if heat be applied to air confined in such a vessel inserted above water, it makes its escape from the vessel and passes through the water. Thermometers are instruments for measuring degrees of heat by the expansion of fluids in narrow tubes. Mercury is generally used, of which 100,000 parts at the freezing point of water become 101,835 parts at the boiling point, and on Fahrenheit's scale these parts are divided into 180 degrees. Solids, by a certain increase of heat, become fluids, and fluids gases, or elastic fluids. Thus ice is converted by heat into water, and by still

more heat it becomes steam; and heat disappears, or, as it is called, is rendered *latent*, during the conversion of solids into fluids, or fluids into gases, and re-appears, or becomes sensible, when gases become fluids, or fluids solids; hence cold is produced during evaporation, and heat during the condensation of steam.

There are a few exceptions to the law of expansion of bodies by heat, which seem to depend either upon some change in their chemical constitution, or on their becoming crystallised. Clay contracts by heat, which seems to be owing to its giving off water. Cast-iron and antimony, when melted, crystallize in cooling, and expand. Ice is much lighter than water. Water expands a little, even before it freezes; and it is of the greatest density at about 41° or 42°, the freezing point being 32°; and this circumstance is of considerable importance in the general economy of nature. The influence of the changes of seasons, and of the position of the sun on the phenomena of vegetation, demonstrates the effects of heat on the functions of plants. The matter absorbed from the soil, must be in a fluid state to pass into their roots; and when the surface is frozen, they can derive no nourishment from it. The activity of chemical changes likewise is increased by a certain increase of temperature; and even the rapidity of the ascent of fluids, by capillary attraction.

This last fact is easily shown, by placing in each of two wine glasses a similar hollow stalk of grass, so bent as to discharge any fluid in the glasses slowly, by capillary attraction: if hot water be in one glass, and cold water in the other, the hot water will be discharged much more rapidly than the cold water. The fermentation and decomposition of animal and vegetable substances require a certain degree of heat, which is con-

sequently necessary for the preparation of the food of plants; and, as evaporation is more rapid in proportion as the temperature is higher, the superfluous parts of the sap are most readily carried off at the time its ascent is quickest.

Two opinions are current respecting the nature of heat. By one School it is conceived to be a peculiar subtile fluid, of which the particles repel each other, but have a strong attraction for the particles of other matter. By another it is considered as a motion or vibration of the particles of matter, which is supposed to differ in velocity in different cases, and thus to produce the different degrees of temperature. Whatever decision be ultimately made respecting these opinions, it is certain that there is matter moving in the space between us and the heavenly bodies capable of communicating heat; the motions of which are rectilinear: thus the solar rays produce heat in acting on the surface of the earth. The experiments of Sir W. Herschel have shown that the calorific effects of the solar rays bear no relation to their illuminating powers, the red rays producing a much greater effect of heat than any of the other coloured rays; and it appears that there are *invisible* rays distinguished by very different degrees of refrangibility, some of which produce *heat*, and others of which are distinguished by their *chemical* effects.

The different influences of the different solar rays on vegetation have not yet been studied; but it is certain that the rays exercise an influence independent of the heat they produce. Thus plants kept in the dark, in a hot-house, grow luxuriantly, but they never gain their natural colours; their leaves are white or pale, and their juices watery and peculiarly saccharine.

The earth, when not exposed to the solar rays, is con-

stantly losing heat by radiation, and different soils have their temperature differently diminished by this cause.

When a piece of sealing-wax is rubbed by a woollen cloth, it gains the power of attracting light bodies, such as feathers or ashes. In this state it is said to be *electrical;* and if a metallic cylinder, placed upon a rod of glass, is brought in contact with the sealing-wax, it likewise gains the momentary power of attracting light bodies, so that electricity, like heat, is communicable. When two light bodies receive the same electrical influence, or are electrified by the same body, they repel each other. When one of them is acted on by sealing-wax, and the other by glass that has been rubbed by woollen, they attract each other; hence it is said that bodies similarly electrified repel each other, and bodies dissimilarly electrified attract each other: and the electricity of glass is called vitreous, or positive electricity, and that of sealing-wax resinous, or negative electricity.

When, of two bodies made to rub each other, one is found positively electrified, the other is always found negatively electrified, and, as in the common electrical machine, these states are capable of being communicated to metals placed upon rods or pillars of glass. Electricity is produced, likewise, by the contact of bodies; thus a piece of zinc and of silver give a slight electrical shock when they are made to touch each other, and to touch the tongue; and when a number of plates of copper and zinc, 100, for instance, are arranged in a pile with cloths, moistened in salt and water, in the order of zinc, copper, moistened cloth, zinc, copper, moistened cloth, and so on, they form an electrical battery, which will give strong shocks and sparks, and which is possessed of remarkable chemical powers. The luminous phenomena, produced by common electricity,

are well known. It would be improper to dwell upon them in this place. They are the most impressive effects occasioned by this agent; and they offer illustrations of lightning and thunder.

Electrical changes are constantly taking place in nature, on the surface of the earth, and in the atmosphere; but as yet the effects of this power in vegetation have not been correctly estimated. It has been shown by experiments made by means of the Voltaic battery (the instrument composed of zinc, copper, and water), that compound bodies in general are capable of being decomposed by electrical powers; and it is probable that the various electrical phenomena occurring in our system must influence both the germination of seeds and the growth of plants. I found that corn sprouted much more rapidly in water positively electrified by the Voltaic instrument than in water negatively electrified; and experiments made upon the atmosphere show that clouds are usually negative; and as, when a cloud is in one state of electricity, the surface of the earth beneath is brought into the opposite state, it is probable, that in common cases the surface of the earth is positive.

Different opinions are entertained amongst scientific men respecting the nature of electricity. By some the phenomena are conceived to depend upon a single subtile fluid in excess in the bodies said to be positively electrified, in deficiency in the bodies said to be negatively electrified. A second class suppose the effects to be produced by two different fluids, called by them the vitreous fluid and the resinous fluid; and an hypothesis has been advanced, in which they are considered as affections or motions of matter, or an exhibition of attractive powers, similar to those which produce chemical combination and decomposition; but usually exerting their action on masses.

The power which gives to a bar or needle of steel the property of directing itself to two points of the globe, called north and south poles, depends upon what is called magnetism. It agrees with electricity in many of its laws; but, as far as our researches have hitherto gone, it is most active in its operation on metals and certain of their combinations. Iron, nickel, and cobalt, are most susceptible of magnetic impressions, and, in the harder compounds of iron, these impressions produce permanent effects; but the recent experiments of M. Arago show, that copper, metals in general, and, probably, all other substances, receive very weak and evanescent magnetism, which seems to differ in intensity for every body. Magnetism is capable of being communicated from bodies endowed with it to others that do not possess it, and is produced whenever concentrated electricity passes through space, its sphere of action or communication being at right angles to the course of the electricity. Thus a bar of steel, placed transversely over a wire conveying an electrical shock, becomes a magnet. The connection of magnetism and electricity is of recent discovery, and the fact which served to establish it was made known by M. Œrsted, a Danish philosopher. It will ultimately probably tend to a more intimate acquaintance with the nature of these two extraordinary agents. The attractive powers of the magnet may be made use of to show the existence of iron in soils, as will be mentioned more particularly hereafter.

The different powers that have been thus generally described continually act upon common matter so as to change its form, and produce arrangements fitted for the purposes of life. Bodies are either simple or compound. A body is said to be simple when it is in-

capable of being resolved into any other forms of matter. Thus, gold or silver, though they may be melted by heat, or dissolved in corrosive menstrua, yet are recovered unchanged in their properties, and they are said to be simple bodies. A body is considered as compound, when two or more distinct substances are capable of being produced from it: thus marble is a compound body; for by a strong heat it is converted into lime, and an elastic fluid is disengaged in the process; and the proof of our knowledge of the true composition of a body is, that it is capable of being reproduced by the same substances as those into which it had been decomposed; thus by exposing lime for a long while to the elastic fluid disengaged during its calcination, it becomes converted into a substance similar to powdered marble. The term element has the same meaning as simple or undecompounded body; but it is applied merely with reference to the present state of chemical knowledge. It is probable that, as yet, we are not acquainted with any of the true elements of matter: many substances, formerly supposed to be simple, have been lately decompounded, and the chemical arrangement of bodies must be considered as a mere expression of facts, the results of accurate statical experiments.

Vegetable substances in general are of a very compound nature, and consist of a great number of elements, most of which belong likewise to the other kingdoms of nature, and are found in various forms. Their more complicated arrangements are best understood after their simpler forms of combination have been examined.

The number of bodies which I shall consider as at present undecomposed, are, as was stated in the intro-

ductory lecture, five acidifying or solvent substances, eight inflammable bodies, and forty metals.*

In most of the inorganic compounds, the nature of which is well known, into which these elements enter, they are combined in definite proportions; so that, if the elements be represented by numbers, the proportions in which they combine are expressed either by those numbers, or by some simple multiples of them.

I shall mention, in a few words, the characteristic properties of the most important simple substances, and the numbers representing the proportions in which they combine in those cases where they have been accurately ascertained.

1. *Oxygen* forms about one-fifth of the air of our atmosphere. It is an elastic fluid, at all known temperatures. Its specific gravity is to that of air as 10,967 to 10,000. It supports combustion with much more vividness than common air; so that if a small steel wire or a watch-spring, having a bit of inflamed wood attached to it, be introduced into a bottle filled with the gas, it burns with great splendour. It is respirable. It is very slightly soluble in water. The number representing the proportion in which it combines is 15.† It may be made by heating a mixture of the mineral called manganese and sulphuric acid together in a proper vessel, or by heating strongly red lead, or red precipitate of mercury.

2. *Chlorine* is, like oxygen, a permanent elastic fluid. Its colour is yellowish green; its smell is very

* Now forty-two metals. Vide note p. 181.

† [According to the most accurate estimate founded on experiments made since 1827, the number representing the proportion in which oxygen combines is 16, that of hydrogen being 2; supposing after the author, that water is composed of two proportions of hydrogen and of one of oxygen.]

disagreeable; it is not respirable; it supports the combustion of all the common inflammable bodies except charcoal; its specific gravity is to that of air as 24,677 to 10,000; it is soluble in about half its volume of water, and its solution in water destroys vegetable colours. Many of the metals (such as arsenic or copper) take fire spontaneously when introduced into a jar or bottle filled with the gas. Chlorine may be procured by heating together a mixture of spirits of salt or muriatic acid, and manganese. The number representing the proportion in which this gas enters into combination is 67.

3. *Fluorine*, or the fluoric principle. This substance has such strong tendencies to combination, that as yet no vessels have been found capable of containing it in its pure form. It may be obtained, combined with hydrogen, by applying heat to a mixture of fluor, or Derbyshire spar, and sulphuric acid; and in this state it is an intensely acid compound, a little heavier than water, and which becomes still denser by combining with water. The existence of fluorine as an element is proved by its expulsion from certain compounds by chlorine, and by its transference from place to place. In attempts made to confine it, so as to examine its properties, it always combines with, or decomposes, the vessels employed; so that, as yet, its physical qualities are unknown: 16 is an approximation to the number representing it.

4. *Iodine*. This substance is procured from the ashes of marine plants, after the extraction of the carbonate of soda, by acting upon them by sulphuric acid. It appears as a dark-coloured solid, having the colour and lustre of plumbago: its specific gravity is about 4; that of water being 1. It fuses at a low temperature, and at

a heat above that of boiling water becomes a violet-coloured gas. It forms an active acid by uniting to hydrogen. The alkaline metals burn, when heated in it. It unites to all the metals upon which its action has been examined.

5. *Brome.* This body has been very recently discovered in sea-water. It is in nature analogous to iodine, and resembles a compound of these two bodies. It is a dense liquid, and forms an orange-coloured gas by a gentle heat.

6. *Hydrogen*, or inflammable air, is the lightest known substance; its specific gravity is to that of air as 732 to 10,000. It burns by the action of an inflamed taper, when in contact with the atmosphere. The proportion in which it combines is represented by unity, or 1. It is procured by the action of diluted oil of vitriol, or hydro-sulphuric acid on filings of zinc or iron. It is the substance employed for filling air-balloons.

7. *Azote* is a gaseous substance, not capable of being condensed by any known degree of cold: its specific gravity is to that of common air as 9516 to 10,000. It does not enter into combustion under common circumstances, but may be made to unite with oxygen by the agency of electrical fire. It forms nearly four-fifths of the air of the atmosphere; and may be procured by burning phosphorus in a confined portion of air. The number representing the proportion in which it combines is 26.

8. *Carbon* is considered as the pure matter of charcoal, and it may be procured by passing spirits of wine through a tube heated red. It has not yet been fused; but rises in vapour at an intense heat. Its specific gravity cannot be easily ascertained; but that of the diamond, which cannot chemically be distinguished from

pure carbon is to that of water as 3500 to 1000. Charcoal has the remarkable property of absorbing several times its volume of different elastic fluids, which are capable of being expelled from it by heat. The number representing it is 11·4.

9. *Sulphur* is the pure substance so well known by that name; its specific gravity is to that of water as 1990 to 1000. It fuses at about 220° Fahrenheit; and at between 500° and 600° takes fire, if in contact with the air, and burns with a pale blue flame. In this process it dissolves in the oxygen of the air, and produces a peculiar acid elastic fluid. The number representing it is 30.

10. *Phosphorus* is a solid of a pale red colour, of specific gravity 1770. It fuses at 90°, and boils at 550°. It is luminous in the air at common temperatures, and burns with great violence at 150°, so that it must be handled with great caution. The number representing it is 222. It is procured by digesting together bone-ashes and oil of vitriol, and strongly heating the fluid substance so produced with powdered charcoal.

11. *Boron* is a solid of a dark olive colour, infusible at any known temperature. It is a substance very lately discovered, and procured from boracic acid. It burns with brilliant sparks when heated in oxygen, but not in chlorine. Its specific gravity, and the number representing it, are not yet accurately known.

12. *Silicon* is procured from silica, or the earth of flints, by the action of potassium: it appears as a dark fawn-coloured powder, which is inflammable, and which produces silica by combustion. It decomposes water and acids; and detonates when heated with alkaline carbonates. It is more analogous to boron in its proper-

ties and chemical habitudes than to any other substance. 32 is an approximation to the number representing silicon.*

13. *Selenion*, or, as M. Berzelius, the discoverer, names it, selenium, is a substance which forms a sort of intermediate link between the inflammable solids and the metals. It is semitransparent, of a red colour, a nonconductor of electricity, of specific gravity about 4300.

14. *Platinum* is one of the noble metals, of rather a duller white than silver, and the heaviest body in nature; its specific gravity being 21,500. It is not acted upon by any acid menstrua except such as contain chlorine; it requires an intense degree of heat for its fusion.

15. The properties of *gold* are well known. Its specific gravity is 19,277. It bears the same relation to acid menstrua as platinum: it is one of the characteristics of both these bodies, that they are very difficultly acted upon by sulphur.

16. *Silver* is of specific gravity 10,400; it burns more readily than platinum or gold, which require the intense heat of electricity. It readily unites to sulphur. The number representing it is 205.

17. *Mercury* is the only known metal fluid at the common temperature of the atmosphere; it boils at 660°, and freezes at 39° below 0. Its specific gravity is 13,560. The number representing it is 380.

18. *Copper* is of specific gravity 8890. It burns when strongly heated, with red flame, tinged with green. The number representing it is 120.

19. *Cobalt* is of specific gravity 7700. Its point of fusion is very high, nearly equal to that of iron. In its

* [Vide Vol. IV. p. 269.]

calcined, or oxidated state, it is employed for giving a blue colour to glass.

20. *Nickel* is of a white colour: its specific gravity is 8820. This metal and cobalt agree with iron in being attractable by the magnet. The number representing nickel is 111.

21. *Iron* is of specific gravity 7700. Its other properties are well known. The number representing it is 103.

22. *Tin* is of specific gravity 7291; it is a very fusible metal, and burns when ignited in the air: the number representing the proportion in which it combines is 110.

23. *Cadmium* is a newly discovered metal, very similar to tin in its sensible properties, of specific gravity about 9000, and is very fusible and volatile.

24. *Zinc* is one of the most combustible of the common metals. Its specific gravity is about 7210. It is a brittle metal under common circumstances; but when heated may be hammered or rolled into thin leaves, and after this operation is malleable. The number representing it is 66.

25. *Lead* is of specific gravity 11,352; it fuses at a temperature rather higher than tin. The number representing it is 398.

26. *Bismuth* is a brittle metal, of specific gravity 9822. It is nearly as fusible as tin; when cooled slowly it crystallizes in cubes. The number representing it is 135.

27. *Antimony* is a metal capable of being volatilized by a strong red heat. Its specific gravity is 6800. It burns, when ignited, with a faint white light. The number representing it is 170.

28. *Arsenic* is of a bluish white colour, of specific

gravity 8310. It may be procured by heating the powder of common white arsenic of the shops strongly in a Florence flask with oil. The metal rises in vapour, and condenses in the neck of the flask. The number representing it is 90.

29. *Manganesum* may be procured from the mineral called manganese, by intensely igniting it in a forge, mixed with charcoal powder. It is a metal very difficult of fusion, and very combustible; its specific gravity is 6850. The number representing it is 177.

30. *Potassium* is the lightest known metal, being only of specific gravity 850. It fuses at about 150°, and rises in vapour at a heat a little below redness. It is a highly combustible substance, takes fire when thrown upon water, burns with great brilliancy, and the product of its combustion dissolves in the water. The number representing it is 75. It may be made by passing fused caustic vegetable alkali, the pure kali of druggists, through iron-turnings strongly ignited in a gun-barrel, or by the electrization of potash by a strong voltaic battery.

31. *Sodium* may be made in a similar manner to potassium: soda, or the mineral alkali, being substituted for the vegetable alkali. It is of specific gravity 940. It is very combustible. When thrown upon water, it swims on its surface, hisses violently, and dissolves, but does not inflame. The number representing it is 88.

32. *Lithium* is a metal procured from a newly-discovered mineral alkali, very similar to sodium in its properties.

33. *Barium* has, as yet, been procured only by electrical powers, and in very minute quantities, so

that its properties have not been accurately examined. The number representing it appears to be 130.

Strontium the 34th, *Calcium* the 35th, *Magnesium* the 36th, *Aluminum* the 37th, *Zirconum* the 38th, *Glucinum* the 39th, and *Ittrium* the 40th of the undecompounded bodies, like barium, have either not been procured absolutely pure or only in such minute quantities that their properties are little known; they are formed either by electrical powers, or by the agency of potassium, from the different earths whose names they bear, with the change of the termination in *um;* and the numbers representing them are believed to be 90 strontium, 40 calcium, 29 magnesium, 33 aluminum, 70 zirconum, 39 glucinum, 111 ittrium.

The remaining simple bodies are metals, most of which, like those just mentioned, can only be procured with very great difficulty; and the substances in general from which they are procured are very rare in nature. They are, *Palladium, Rhodium, Osmium, Iridium, Columbium, Chromium, Molybdenum, Cerium, Tellurium, Tungstenum, Titanium, Uranium.* The numbers representing these last bodies have not yet been determined with sufficient accuracy to render a reference to them of any utility.

The undecompounded substances unite with each other, and the most remarkable compounds are formed by the combinations of oxygen and chlorine with inflammable bodies and metals; and these combinations usually take place with much energy, and are associated with fire.

Combustion, in fact, in common cases, is the process of the solution of a body in oxygen, as happens when sulphur, or charcoal is burnt; or the fixation of oxygen by the combustible body in a solid form, which takes

place when most metals are burnt, or when phosphorus inflames; or the production of a fluid from both bodies, as when hydrogen and oxygen unite to form water.

When considerable quantities of oxygen or of chlorine unite to metals or inflammable bodies, they often produce acids; thus sulphurous, phosphoric, and boracic acids, are formed by a union of considerable quantities of oxygen with sulphur, phosphorus, and boron; and muriatic acid gas is formed by the union of chlorine and hydrogen.

When smaller quantities of oxygen or chlorine unite with inflammable bodies or metals, they form substances not acid, and more or less soluble in water; and the metallic oxides, the fixed alkalies, and the earths, all bodies connected by analogies, are produced by the union of metals with oxygen.

The composition of any compounds, the nature of which is well known, may be easily learned from the numbers representing their elements; all that is necessary is to know how many proportions enter into union. Thus *potassa*, or the pure caustic vegetable alkali, consists of one proportion of potassium and one of oxygen, and its constitution is, consequently, 75 potassium, 15 oxygen.

Carbonic acid is composed of two proportions of oxygen 30, and one of carbon 11·4.

Again, *lime* consists of one proportion of calcium and one of oxygen, and it is composed of 40 of calcium and 15 of oxygen. And *carbonate of lime*, or pure chalk, consists of one proportion of carbonic acid 41·4, and one of lime 55.

Water consists of two proportions of hydrogen 2, and one of oxygen 15: and when water unites to other

bodies in definite proportions, the quantity is 17, or some multiple of 17, *i. e.* 34 or 51, or 68, &c.

Soda, or the mineral alkali, contains two proportions of oxygen to one of sodium.

Ammonia, or the volatile alkali, is composed of six proportions of hydrogen and one of azote.

Amongst the earths, *Silica*, or the earth of flints, probably consists of two proportions of oxygen to one of silicon; and *Magnesia*, *Strontia*, *Baryta*, or *Barytes*, *Alumina*, *Zircona*, *Glucina*, and *Ittria*, of one proportion of metal and one of oxygen.

The *metallic oxides* in general consist of the metals united to from one to four proportions of oxygen; and there are, in some cases, many different oxides of the same metal: thus there are three oxides of lead; the yellow oxide, or massicot, contains two *proportions* of oxygen; the *red oxide*, or *minium*, three; and the *puce-coloured oxide*, four proportions. Again, there are *two oxides* of *copper*, the *black* and the *orange;* the black contains two proportions of oxygen, the orange one.

For pursuing experiments on the composition of such bodies as are connected with agricultural chemistry, a few only of the undecompounded substances are necessary; and amongst the compounded bodies, the common acids, the alkalies, and the earths, are the most essential substances. The elements found in vegetables, as has been stated in the introductory lecture, are very few. Oxygen, hydrogen, and carbon constitute the greatest part of their organized matter. Azote, phosphorus, sulphur, manganesum, iron, silicum, calcium, aluminum, and magnesium, likewise in different arrangements, enter into their composition, or are found in the agents to which they are exposed; and these twelve undecompounded substances are the ele-

ments, the study of which is of the most importance to the agricultural chemist.

The doctrine of definite combinations, as will be shown in the following lectures, will assist us in gaining just views respecting the composition of plants, and the economy of the vegetable kingdom; but the same accuracy of weight and measure, the same statical results, which depend upon the uniformity of the laws that govern dead matter, cannot be expected in operations where the powers of life are concerned, and where a diversity of organs and of functions exist. The classes of definite inorganic bodies, even if we include all the crystalline arrangements of the mineral kingdom, are few, compared with the forms and substances belonging to animated nature. Life gives a peculiar character to all its productions; the power of attraction and repulsion, combination and decomposition, are subservient to it; a few elements, by the diversity of their arrangement, are made to form the most different substances; and similar substances are produced from compounds which, when superficially examined, appear entirely different.

LECTURE III.

On the Organization of Plants.—Of the Roots, Trunk, and Branches. —Of their Structure.—Of the Epidermis.—Of the Cortical and Alburnous Parts.—Of Leaves, Flowers and Seeds.—Of the Chemical Constitution of the Organs of Plants, and the Substances found in them. —Of Mucilaginous, Saccharine, Extractive, Resinous and Oily Substances, and other Vegetable Compounds; their Arrangements in the Organs of Plants, their Composition, Changes, and Uses.

VARIETY characterises the vegetable kingdom; yet there is an analogy between the forms and the functions of all the different classes of plants, and on this analogy the scientific principles relating to their organization depend.

Vegetables are living structures, distinguished from animals by exhibiting no signs of perception, or of voluntary motion; and their organs are either organs of nourishment or of reproduction; organs for the preservation and increase of the individual or for the multiplication of the species.

In the living vegetable system there are to be considered, the exterior form, and the interior constitution.

Every plant examined as to external structure, displays at least four systems of organs—or some analogous parts. First, the *Root.* Secondly, the *Trunk and Branches*, or *Stem.* Thirdly, the *Leaves;* and, fourthly, the *Flowers* or *Seeds.*

The *root* is that part of the vegetable which least impresses the eye; but it is absolutely necessary. It

attaches the plant to the surface, is its organ of nourishment, and the apparatus by which it imbibes food from the soil.—The roots of plants, in their anatomical division, are very similar to the trunk and branches. The root may indeed be said to be a continuation of the trunk, terminating in minute ramifications and filaments, and not in leaves.

When the branch or the root of a tree is cut transversely, it usually exhibits three distinct bodies: the bark, the wood, and the pith: and these again are individually susceptible of a new division.

The bark, when perfectly formed, is covered by a thin cuticle, or *epidermis*, which may be easily separated. It is generally composed of a number of laminæ or scales, which in old trees are usually in a loose and decaying state. The epidermis is not vascular, and it merely defends the interior parts from injury. In forest trees, and in the larger shrubs, the bodies of which are firm, and of strong texture, it is a part of little importance; but in the reeds, the grasses, canes, and the plants having hollow stalks, it is of great use, and is exceedingly strong, and in the microscope seems composed of a kind of glassy net-work, which is principally siliceous earth.

This is the case in wheat, in the oat, in different species of equisetum, and, above all, in the rattan, the epidermis of which contains a sufficient quantity of flint to give light when struck by steel; or two pieces rubbed together produce sparks. This fact first occurred to me in 1798, and it led to experiments, by which I ascertained that siliceous earth existed generally in the epidermis of the hollow plants.

The siliceous epidermis serves as a support, protects the bark from the action of insects, and seems to per-

form a part in the economy of these feeble vegetable tribes, similar to that performed in the animal kingdom by the shell of the crustaceous insects.

Immediately beneath the epidermis is the *parenchyma.* It is a soft substance, consisting of cells, filled with fluid, having almost always a greenish tint. The cells in the parenchymatous part, when examined by the microscope, appear hexagonal. This form, indeed, is that usually affected by the cellular membranes in vegetables, and it seems to be the result of the general reaction of the solid parts, similar to that which takes place in the honeycomb. This arrangement, which has usually been ascribed to the skill and artifice of the bee, seems, as Dr. Wollaston has observed, to be merely the result of the mechanical laws which influence the pressure of cylinders composed of soft materials, the nest of solitary bees being uniformly circular.*

The innermost part of the bark is constituted by the *cortical layers,* and their numbers vary with the age of the tree. On cutting the bark of a tree of several years' standing, the productions of different periods may be distinctly seen, though the layer of every particular year can seldom be accurately defined.

The cortical layers are composed of fibrous parts, which appear interwoven, and which are transverse and longitudinal. The transverse are membranous and porous, and the longitudinal are generally composed of tubes.

The functions of the parenchymatous and cortical parts of the bark are of great importance. The tubes of the fibrous parts appear to be the organs that receive the sap; the cells seem destined for the elaboration of its parts, and for the exposure of them to the action of

* [This idea, was afterwards relinquished by Dr. Wollaston; he returned to the commonly received opinion on the subject.]

PLATE. 2.

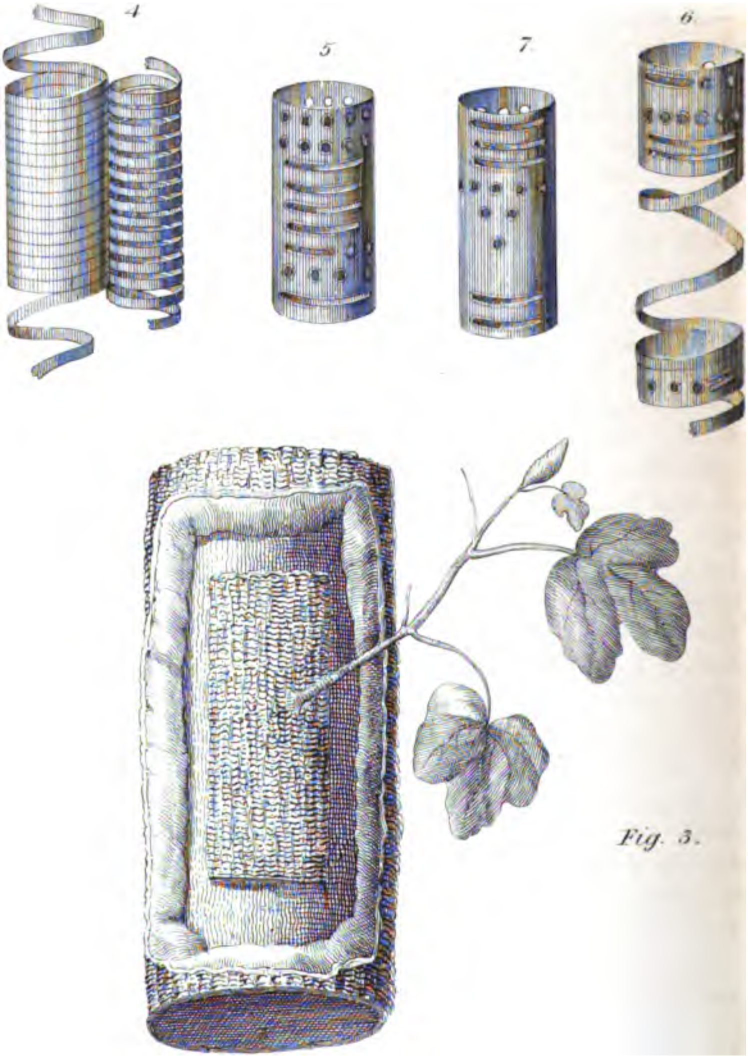


Fig. 3.

the atmosphere, and the new matter is annually produced in the spring, immediately on the inner surface of the cortical layer of the last year.

It has been shown by the experiments of Mr. Knight, and those made by other physiologists, that the sap descending through the bark after being modified in the leaves, is the principal cause of the growth of the tree: thus, if the bark is wounded the principal formation of new bark is on the upper edge of the wound; and when the wood has been removed, the formation of new wood takes place immediately beneath the bark: and every vessel and passage in the bark and wood of trees seems capable of carrying fluids in different and opposite directions, though more readily and copiously in one direction than in others, which offer something analagous to the anastomosis of vessels in animal bodies. A fact noticed by M. Palisot de Beauvois, is explained on this principle. That gentleman separated different portions of cortical layers from the rest of the bark in several trees, and found that in most instances the separated bark grew in the same manner as the bark in its natural state. The experiment was tried with most success on the lime-tree, the maple, and the lilac; the layers of bark were removed in August 1810, and in the spring of the next year, in the case of the maple and the lilac, small annual shoots were produced in the parts where the bark was insulated.*

The wood of trees is composed of an external part, called *alburnum* or *sap-wood*, and of an internal part, the *heart-wood*. The alburnum is white, and full of moisture, and in young trees and annual shoots it reaches even to the pith. The alburnum is the great

* Fig. 3. represents the result of the experiment on the maple. Journal de Physique, September, 1811, p. 210.

vascular system of the vegetable through which the sap rises, and the vessels in it extend from the leaves to the minutest filaments in the roots.

There is in the alburnum a membranous substance, composed of cells, which are constantly filled with the sap of the plant; and there are in the vascular system several different kinds of tubes; Mirbel has distinguished four species—the *simple tubes*, the *porous tubes*, the *tracheæ*, and the *false tracheæ*.*

The tubes which he has called simple tubes, seem to contain the resinous or oily fluids peculiar to different plants.

The porous tubes likewise contain these fluids; and their use is probably that of conveying them into the sap for the production of new arrangements.

The tracheæ contain fluid matter, which is always thin, watery, and pellucid; and these organs, as well as the false tracheæ, probably carry off water from the denser juices, which are thus enabled to consolidate for the production of new wood.

In the arrangement of the fibres of the wood, there are two distinct appearances. There are series of white and shining laminæ, which shoot from the centre towards the circumference, and these constitute what is called the *silver grain* of the wood.

There are likewise numerous series of concentric layers, which are usually called the *spurious grain*, and their number denotes the age of the tree.†

The silver grain is elastic and contractile; and it has

* Figs. 4, 5, 6, and 7, represent Mirbel's idea of the simple tubes, the porous tubes, the tracheæ, and the false tracheæ.

† Fig. 8. represents the section of an elm branch, which exhibits the tubular structure and the silver and spurious grain. Fig. 9. represents the section of part of the branch of an oak. Fig. 10. that of the branch of an ash.

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PLATE. 3

Fig. 8.

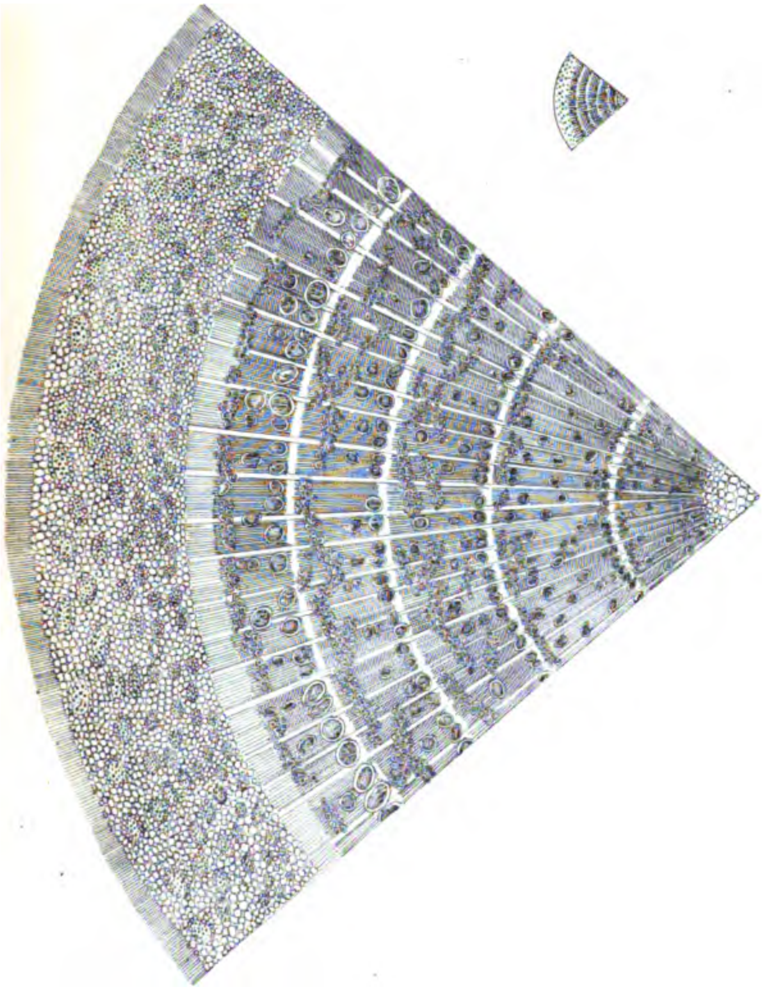


PLATE 4.

Fig. 9.

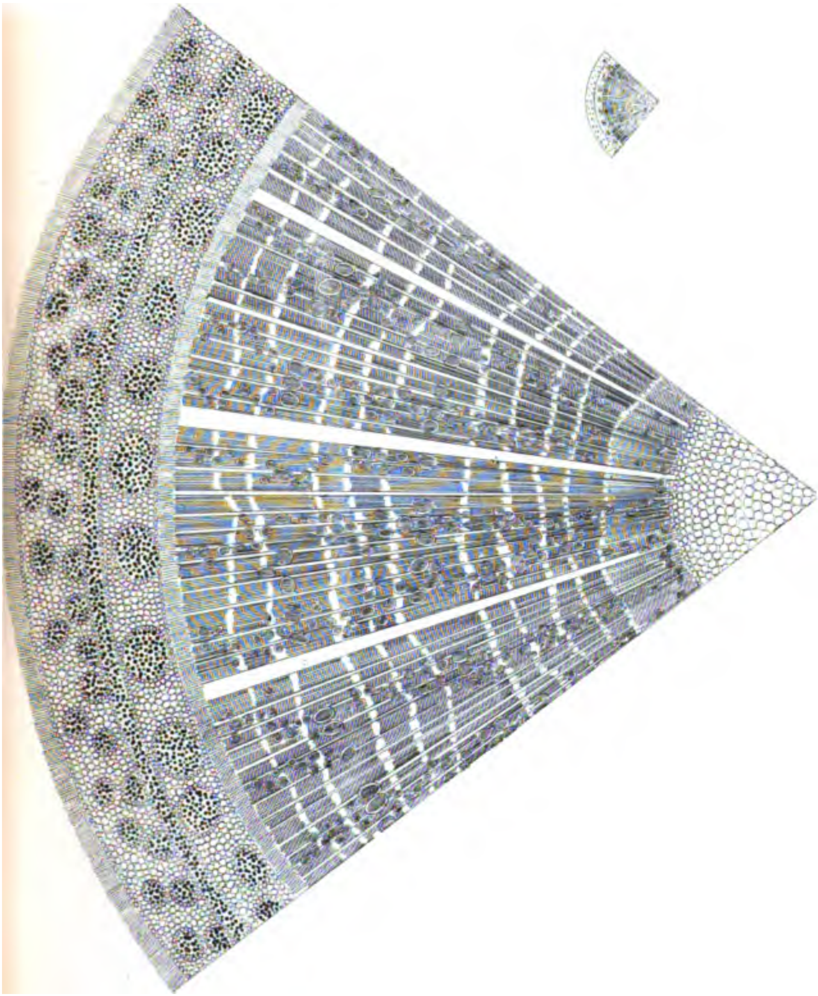
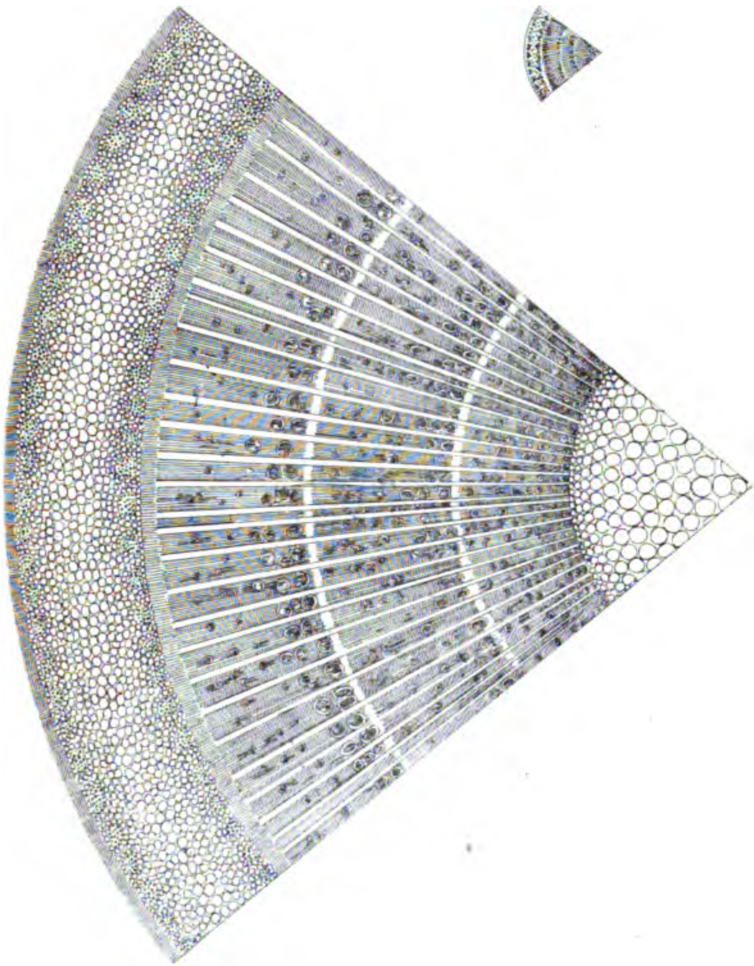


PLATE. 5.

Fig. 10.



been supposed by Mr. Knight, that the contractions produced in it by changes of temperature are the principal causes of the ascent of the sap.

The silver grain is most distinct in forest trees; but even annual shrubs have a system of fibres similar to it. The analogy of nature is constant and uniform, and similar effects are usually produced by similar organs.

The *pith* occupies the centre of the wood; its texture is membranous; it is composed of cells, which are circular towards the extremity, and hexagonal in the centre of the substance. In the first infancy of the vegetable, the pith occupies but a small space. It gradually dilates, and in annual shoots and young trees offers a considerable diameter. In the more advanced age of the tree, acted on by the heart-wood, pressed by the new layers of the alburnum, it begins to diminish, and in very old forest trees becomes almost imperceptible.

Many different opinions have prevailed with regard to the use of the pith. Dr. Hales supposed that it was the great cause of the expansion and development of the other parts of the plant; that being the most interior, it was likewise the most acted upon of all the organs, and that from its re-action the phenomena of their development and growth resulted.

Linnæus, whose lively imagination was continually employed in endeavours to discover analogies between the animal and vegetable systems, conceived "that the pith performed for the plant the same functions as the brain and nerves in animated beings." He considered it as the organ of irritability, and the seat of life.

The latest discoveries have proved that these two opinions are equally erroneous. Mr. Knight has re-

moved the pith in several young trees, and they continued to live and to increase.

It is evidently, then, only an organ of secondary importance. In early shoots, in vigorous growth, it is filled with moisture; and it is a reservoir, perhaps of fluid nourishment at the time it is most wanted. As the heart-wood forms, it is more and more separated from the living part, the alburnum; its functions become extinct, it diminishes, dies, and at last disappears.

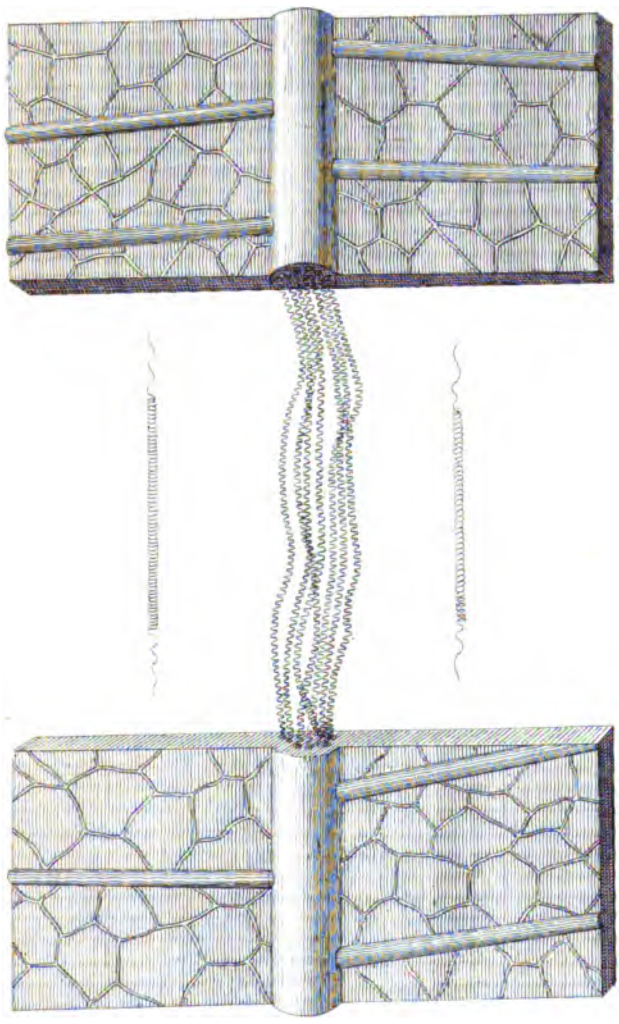
The *tendrils*, the *spines*, and other similar parts of plants, are analogous in their organization to the branches, and offer a similar cortical and alburnous organization. It has been shown, by the late observations of Mr. Knight, that the directions of tendrils, and the spiral form they assume, depend upon the unequal action of light upon them; and a similar reason has been assigned by M. De Candolle to account for the turning of the parts of plants towards the sun: that ingenious physiologist supposes that the fibres are shortened by the chemical agency of the solar rays upon them, and that, consequently, the parts will move towards the light.

The *leaves*, the great sources of the permanent beauty of vegetation, though infinitely diversified in their forms, are in all cases similar in interior organization, and perform the same functions.

The alburnum spreads itself from the foot-stalks into the very extremity of the leaf; it retains its vascular system and its living powers; and its peculiar tubes, particularly the tracheæ, may be distinctly seen in the leaf.*

* Fig. 11. represents part of a leaf of a vine magnified and cut, so as to exhibit the tracheæ; it is copied, as are also the preceding figures, from Grew's Anatomy of Plants.

Fig: 11.



The green membranous substances may be considered as an extension of the parenchyma, and the fine and thin covering as the epidermis. Thus the organization of the roots and branches may be traced into the leaves, which present, however, a more perfect, refined, and minute structure.

One great use of the leaves is for the exposure of the sap to the influence of the air, heat, and light. Their surface is extensive, the tubes and cells very delicate, and their texture porous and transparent.

In the leaves much of the water of the sap is evaporated; it is combined with new principles, and fittted for its organizing functions, and probably passes, in its prepared state, from the extreme tubes of the alburnum into the ramifications of the cortical tubes, and then descends through the bark.

On the upper surface of leaves, which is exposed to the sun, the epidermis is thick but transparent, and is composed of matter possessed of little organization, which is either principally earthy, or consists of some homogeneous chemical substance. In the grasses it is partly siliceous, in the laurel resinous, and in the maple and thorn it is principally constituted by a substance analogous to wax.

By these arrangements any evaporation, except from the appropriated tubes, is prevented.

On the lower surface the epidermis is a thin transparent membrane full of cavities, and it is probably altogether by this surface that moisture and the principles of the atmosphere necessary to vegetation are absorbed.

If a leaf be turned, so as to present its lower surface to the sun, its fibres will twist so as to bring it as much as possible into its original position; and all leaves

elevate themselves on the foot-stalk during their exposure to the solar light, and as it were move towards the sun.

This effect seems, in a great measure, dependent upon the mechanical and chemical agency of light and heat. Bonnet made artificial leaves, which when a moist sponge was held under the lower surface, and a heated iron above the upper surface, turned exactly in the same manner as the natural leaves. This, however, can be considered only as a very rude imitation of the natural process.

What Linnæus has called the sleep of the leaves, appears to depend wholly upon the suspension of the action of light and heat, and on the operation of moisture.

This singular but constant phenomenon had never been scientifically observed, till the attention of the botanist of Upsal was fortunately directed to it. He was examining particularly a species of lotus, in which four flowers had appeared during the day, and he missed two in the evening; by accurate inspection, he soon discovered that these two were hidden by the leaves, which had closed round them. Such a circumstance could not be lost upon so acute an observer. He immediately took a lantern, went into his garden, and witnessed a series of curious facts before unknown. All the simple leaves of the plants he examined, had an arrangement totally different from their arrangement in the day: and the greater number of them were seen closed or folded together.

The sleep of leaves is, in some cases, capable of being produced artificially. De Candolle made this experiment on the sensitive plant. By confining it in a dark place in the day-time, the leaves soon closed; but, on

illuminating the chamber with many lamps, they again expanded. So sensible were they to the effects of light and radiant heat.

In the greater number of plants the leaves annually decay, and are re-produced; their decay takes place either at the conclusion of the summer, as in very hot climates, when they are no longer supplied with sap, in consequence of the dryness of the soil, and the evaporating powers of heat; or, in the autumn, as in the northern climates, at the commencement of the frosts. The leaves preserve their functions, in common cases, no longer than there is a circulation of fluids through them. In the decay of the leaf, the colour assumed seems to depend upon the nature of the chemical change; and as acids are generally developed, it is usually either reddish-brown or yellow; yet there are great varieties. Thus, in the oak, it is bright brown; in the beech, orange; in the elm, yellow; in the vine, red; in the sycamore, dark-brown; in the cornel-tree, purple; and, in the woodbine, blue.

The cause of the preservation of the leaves of evergreens through the winter, is not accurately known. From the experiments of Hales, it appears that the force of the sap is much less in plants of this species, and probably there is a certain degree of motion in it, in warm days, even in winter; their juices are less watery than those of other plants, and probably less liable to be congealed by cold, and certainly not so easy of decomposition; and their vessels are defended by stronger coatings from the action of the elements.

The production of the other parts of the plant takes place at the time the leaves are most vigorously performing their functions. If the leaves are stripped off from a tree in spring, it uniformly dies; and when many of the

leaves of forest trees are injured by blasts, or long-continued dryness, the trees always become stag-headed and unhealthy.

The leaves are necessary for the existence of the individual tree; the *flowers* for the continuance of the species. Of all the parts of plants they are the most refined, the most beautiful in their structure; and appear as the master-work of nature in the vegetable kingdom. The elegance of their tints, the variety of their forms, the delicacy of their organization, and the adaptation of their parts, are all calculated to awaken our curiosity, and excite our admiration.

In the flower there are to be observed—1st, the *calyx*, or green membranous part, forming the support for the coloured floral leaves. This is vascular, and agrees with the common leaf in its texture and organization; it defends, supports, and nourishes the more perfect parts. 2d, The *corolla*, which consists either of a single piece, when it is called monopetalous; or of many pieces, when it is called polypetalous. It is usually very vivid in its colours, is filled with an almost infinite variety of small tubes of the porous kind; it incloses and defends the essential parts in the interior, and supplies the juices of the sap to them. These parts are,—3d, the *stamens* and the *pistils.*

The essential part of the stamens are the summits or *anthers*, which are usually circular, and of a highly vascular texture, and covered with a fine dust called the *pollen*.

The pistil is cylindrical, and surmounted by the *style*; the top of which is generally round and protuberant.*

In the pistil, when it is examined by the microscope,

* Fig. 12. represents the common lily; *a* the corolla, *bbbbb* the anthers, *c* the pistil.

Fig 12

Fig 13

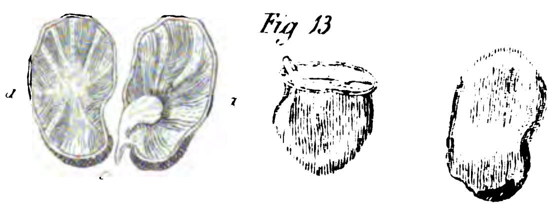
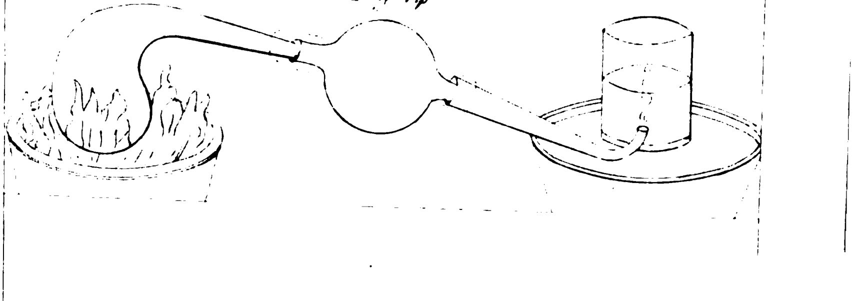


Fig 14



congeries of spherical forms may usually be perceived, which seem to be the bases of the future seeds.

It is upon the arrangement of the stamens and the pistils, that the Linnæan classification is founded. The numbers of the stamens and pistils in the same flower, their arrangements, or their division in different flowers, are the circumstances which guided the Swedish philosopher, and enabled him to form a system admirably adapted to assist the memory, and render botany of easy acquisition; and which, though it does not always associate together the plants most analogous to each other in their general characters, is yet so ingeniously contrived as to denote all the analogies of their most essential parts.

The pistil is the organ which contains the rudiments of the seed; but the seed is never formed as a re-productive germ, without the influence of the pollen, or dust on the anthers.

This mysterious impression is necessary to the continued succession of the different vegetable tribes. It is a feature which extends the resemblances of the different orders of beings, and establishes, on a great scale, the beautiful analogy of nature.

The Ancients had observed that different date trees bore different flowers, and that those trees producing flowers which contained pistils, bore no fruit, unless in the immediate vicinity of such trees as produced flowers containing stamens. This long-established fact strongly impressed the mind of Malpighi, who ascertained several analogous facts with regard to other vegetables. Grew, however, was the first person who attempted to generalize upon them; and much just reasoning on the subject may be found in his works. Linnæus gave a scientific and distinct form to that which Grew had only

generally observed, and has the glory of establishing what has been called the sexual system, upon the basis of minute observations and accurate experiments.

The *seed*, the last production of vigorous vegetation, is wonderfully diversified in form. Being of the highest importance to the resources of nature, it is defended above all other parts of the plant; by soft pulpy substances, as in the esculent fruits; by thick membranes, as in the leguminous vegetables; and by hard shells, or a thick epidermis, as in the palms and grasses.

In every seed there is to be distinguished, 1. the *organ of nourishment;* 2. the nascent plant, or the *plume;* 3. the nascent root, or the *radicle.*

In the common garden bean, the organ of nourishment is divided into two lobes called *cotyledons;* the plume is the small white point between the upper part of the lobes; and the radicle is the small curved cone at their base.*

In wheat, and in many of the grasses, the organ of nourishment is a single part, and these plants are called *monocotyledonous.* In other cases it consists of more than two parts, when the plants are called *polycotyledonous.* In the greater number of instances, it is, however, simply divided into two, and is *dicotyledonous.*

The matter of the seed, when examined in its common state, appears dead and inert: it exhibits neither the forms nor the functions of life. But let it be acted upon by moisture, heat, and air, and its organized powers are soon distinctly developed. The cotyledons expand, the membranes burst, the radicle acquires new matter, descends into the soil, and the plume rises towards the free air. By degrees the organs of nourish-

* Fig. 13. represents the garden bean; *aa* the cotyledons, *b* the plume, *c* the radicle.

ment of dicotyledonous plants become vascular, and are converted into seed leaves, and the perfect plant appears above the soil. Nature has provided the elements of germination on every part of the surface; water and pure air and heat are universally active, and the means for the preservation and multiplication of life are at once simple and grand.

To enter into more minute details on the vegetable physiology would be incompatible with the objects of these Lectures. I have attempted only to give such general ideas on the subject as may enable the philosophical agriculturist to understand the functions of plants; those who wish to study the anatomy of vegetables, as a distinct science, will find abundant materials in the works of the authors I have quoted, page 182, and likewise in the writings of Linnæus, Desfontaines, De Candolle, De Saussure, Bonnet, and Smith.

The history of the peculiarities of structure in the different vegetable classes rather belongs to botanical than agricultural knowledge. As I mentioned in the commencement of this Lecture, their organs are possessed of the most distinct analogies, and are governed by the same laws. In the grasses and palms, the cortical layers are larger in proportion than the other parts; but their uses seem to be the same as in forest trees.

In bulbous roots, the alburnous substance forms the largest part of the vegetable; but in all cases it seems to contain the sap, or solid materials deposited from the sap.

The slender and comparatively dry leaves of the pine and the cedar perform the same functions as the large and juicy leaves of the fig-tree, or the walnut.

Even in the cryptogamia class, where no flowers are distinct, still there is every reason to believe that the

production of the seed is effected in the same way as in the more perfect plants. The mosses and lichens, which belong to this family, have no distinct leaves, or roots, but they are furnished with filaments which perform the same functions; and even in the fungus and the mushroom there is a system for the absorption and aëration of the sap.

It was stated in the last Lecture, that all the different parts of plants are capable of being decomposed into a few elements. Their uses as food, or for the purposes of the arts, depend upon compound arrangements of those elements which are capable of being produced either from their organized parts, or from the juices they contain; and the examination of the nature of these substances is an essential part of Agricultural Chemistry.

Oils are expressed from the fruits of many plants: resinous fluids exude from the wood; saccharine matters are afforded by the sap; and dyeing materials are furnished by leaves, or the petals of flowers: but particular processes are necessary to separate the different compound vegetable substances from each other; such as maceration, infusion, or digestion in water, or in spirits of wine: but the application and the nature of these processes will be better understood when the chemical nature of the substances is known; the consideration of them will therefore be reserved for another place in this Lecture.

The compound substances found in vegetables are, 1. gum, or mucilage, and its different modifications; 2. starch; 3. sugar; 4. albumen; 5. gluten; 6. gum elastic; 7. extract; 8. tannin; 9. indigo; 10. colouring principles; 11. bitter principles; 12. wax; 13. resins; 14. camphor; 15. fixed oils; 16. volatile oils;

17. woody fibre; 18. acids; 19. alkalies, earths, metallic oxides, and saline compounds.

I shall describe generally the properties and composition of these bodies, and the manner in which they are procured.

1. *Gum* is a substance which exudes from certain trees; it appears in the form of a thick fluid, but soon hardens in the air, and becomes solid: when it is white, or yellowish white, more or less transparent, and somewhat brittle, its specific gravity varies from 1300 to 1490.

There is a great variety of gums, but the best known are gum arabic, gum senegal, gum tragacanth, and the gum of the plum or cherry tree. Gum is soluble in water, but not soluble in spirits of wine. If a solution of gum be made in water, and spirits of wine or alcohol be added to it, the gum separates in the form of white flakes. Gum can be made to inflame only with difficulty; much moisture is given off in the process, which takes place with a dark smoke and feeble blue flame, and a coal remains.

The characteristic properties of gum are its easy solubility in water, and its insolubility in alcohol. Different chemical substances have been proposed for ascertaining the presence of gum, but there is reason to believe that few of them afford accurate results; and most of them (particularly the metallic salts), which produce changes in solutions of gum, may be conceived to act rather upon some saline compounds existing in the gum, than upon the pure vegetable principle.

Mucilage must be considered as a variety of gum; it agrees with it in its most important properties, but seems to have less attraction for water. According to Hermbstadt, when gum and mucilage are dissolved to-

gether in water, the mucilage may be separated by means of sulphuric acid. Mucilage may be procured from linseed, from the bulbs of the hyacinth, from the leaves of the marshmallows, from several of the lichens, and from many other vegetable substances.

From the analysis of MM. Gay Lussac and Thenard, it appears that gum arabic contains, in 100 parts,

Of carbon - - -	42·23
oxygen - - -	50·84
hydrogen - - -	6·93
With a small quantity of saline and earthy matter.	——
Or, of carbon - - -	42·23
Oxygen and hydrogen in the proportions necessary to form water - -	57·77

This estimation agrees very nearly with the definite proportions of 11 of carbon, 10 of oxygen, and 20 of hydrogen.

All the varieties of gum and mucilage are nutritious as food. They either partially or wholly lose their solubility in water, by being exposed to a heat of 500° or 600° Fahrenheit, but their nutritive powers are not destroyed, unless they are decomposed. Gum and mucilage are employed in some of the arts, particularly in calico-printing; till lately, in this country, the calico-printers used gum arabic; but many of them, at the suggestion of Lord Dundonald, now employ the mucilage from lichens.

2. *Starch* is procured from different vegetables, but particularly from wheat or from potatoes. To make starch from wheat the grain is steeped in cold water till it becomes soft, and yields a milky juice by pressure;

it is then put into sacks of linen, and pressed in a vat filled with water: as long as any milky juice exudes the pressure is continued: the fluid gradually becomes clear, and a white powder subsides, which is starch.

Starch is soluble in boiling water, but not in cold water, nor in spirits of wine. It is a characteristic property of starch to be rendered blue by iodine.

Starch is more readily combustible than gum; when thrown upon red-hot iron, it burns with a kind of explosion, and scarcely any residuum remains. According to MM. Gay Lussac and Thenard, 100 parts of starch are composed of,

Carbon, with a small quantity of saline and earthy matter	43·55
Oxygen - - -	49·68
Hydrogen - - -	6·77
Or,	
Carbon - - -	43·55
Oxygen and hydrogen in the proportions necessary to form water - -	56·45

Supposing this estimation correct, starch may be conceived to be constituted by 15 proportions of carbon, 13 of oxygen, and 26 of hydrogen.

Starch forms a principal part of a number of esculent vegetable substances. Sowans, cassava, salop, sago, all of them owe their nutritive powers principally to the starch they contain.

Starch has been found in the following plants:—

Burdock (*Arctium Lappa*), Deadly Nightshade (*Atropa Belladone*), Bistort (*Polygonum Bistorta*), White Bryony (*Bryonia alba*), Meadow Saffron (*Colchicum autumnale*), Dropwort (*Spiræa Filipendula*), Buttercup (*Ranunculus bulbosus*), Figwort (*Scrophularia nodosa*),

Dwarf Elder (*Sambucus ebulus*), Common Elder (*Sambucus Nigra*), Foolstones (*Orchis Morio*), Alexanders (*Imperatoria Ostruthium*), Herbane (*Hyoscyamus niger*), Broad-leaved Dock (*Rumex obtusifolius*), Sharp-pointed Dock (*Rumex acutus*), Water Dock (*Rumex aquaticus*), Wake Robin (*Arum maculatum*), Salep (*Orchis mascula*), Flower de Luce, or Water-flag (*Iris Pseudacorus*), Stinking Gladwyn (*Iris fœtidissima*), Earthnut (*Bunium Bulbocastanum*).

3. *Sugar* in its purest state is prepared from the expressed juice of the *Saccharum officinarum*, or sugar-cane: the acid in this juice is neutralized by lime, and the sugar is crystallized by the evaporation of the aqueous parts of the juice, and slow cooling: it is rendered white by the gradual filtration of water through it. In the common process of manufacture, the whitening or refining of sugar is only effected in a great length of time; the water being gradually suffered to percolate through a stratum of clay above the sugar. As the colouring matter of sugar is soluble in a saturated solution of sugar, or syrup, it appears that refining may be much more rapidly and economically performed by the action of syrup on coloured sugar.* The sensible properties of sugar are well known. Its specific gravity according to Fahrenheit is about 1·6. It is

* A French gentleman lately in this country stated to the West India planters, that he was in possession of a very expeditious and economical method of purifying and refining sugar, which he was willing to communicate to them for a very great pecuniary compensation. His terms were too high to be acceded to. Conversing on the subject with Sir Joseph Banks, I mentioned to him that I thought it probable that raw sugar might be easily purified by passing syrup through it, which would dissolve the colouring matter. The same idea seems to have occurred about the same time, or before, to the late Edward Howard, Esq., who proved its efficacy experimentally, and some time before his death took out a patent for various improvements in the manufacture of sugar.

soluble in its own weight of water at 50°; it is likewise soluble in alcohol, but in smaller proportions.

Lavoisier concluded from his experiments, that sugar consists in 100 parts of

28 carbon,
8 hydrogen,
64 oxygen.

Dr. Thompson considers 100 parts of sugar as composed of

27·5 carbon,
7·8 hydrogen,
64·7 oxygen.

According to the recent experiments of Gay Lussac and Thenard, sugar consists of 42·47 of carbon, and 57·53 of water or its elements.

Lavoisier's and Dr. Thompson's analyses agree very nearly with the proportions of

3 of carbon,
4 of oxygen,
and 8 of hydrogen.

Gay Lussac's and Thenard's estimation gives the same elements as in gum; 11 of carbon, 10 of oxygen, 20 of hydrogen.

It appears from the experiments of Proust, Achard, Goettling, and Parmentier, that there are many different species of sugar ready formed in the vegetable kingdom. The sugar of the American maple, *Acer saccharinum*, is precisely the same as that of the cane. This sugar is used by the North American farmers, who procure it by a kind of domestic manufacture. The trunk of the tree is bored early in spring, to the depth of about two inches; a wooden spout is introduced into the hole; the juice flows for about five or six weeks. A common-sized tree, that is, a tree from two to three feet in diameter, will yield about 200 pints of sap, and

every 40 pints of sap afford about a pound of sugar. The sap is neutralized by lime, and deposits crystals of sugar by evaporation.

The *sugar of grapes* has been lately employed in France as a substitute for colonial sugar. It is procured from the juice of ripe grapes by evaporation and the action of pot-ashes; it is less sweet than common sugar, and its taste is peculiar: it produces a sensation of cold while dissolving in the mouth; and, it is probable, contains a larger portion of water, or its elements.

The roots of the beet (*Beta vulgaris* and *cicla*) afford sugar by boiling, and the evaporation of the extract: it crystallizes and does not differ in its properties from the sugar of the cane in France.

Manna, a substance which exudes from various trees, particularly from the *Fraxinus Ornus*, a species of ash, which grows abundantly in Sicily and Calabria, may be regarded as a variety of sugar very analagous to the sugar of grapes. A substance analagous to manna has been extracted by Fourcroy and Vauquelin from the juice of the common onion (*Allium Cepa*).

Besides the crystallised and solid sugars, there appears to be a sugar which cannot be separated from water, and which exists only in a fluid form; it constitutes a principal part of melasses or treacle; and it is found in a variety of fruits: it is more soluble in alcohol than solid sugar.

The simplest mode of detecting sugar is that recommended by Margraaf. The vegetable is to be boiled in a small quantity of alcohol; solid sugar, if any exist, will separate during the cooling of the solution.

Sugar has been extracted from the following vegetable substances:

The sap of the Birch (*Betula alba*), of the Sycamore (*Acer Pseudoplatanus*), of the Bamboo (*Arundo Bamboo*), of the Maize (*Zea mays*), of the Cow Parsnip (*Heracleum Spondylium*), of the Cocoa-nut tree (*Cocos nucifera*), of the Walnut-tree (*Juglans alba*), of the American aloes (*Agave Americana*), of the Dulse (*Fucus palmatus*), of the Common Parsnip (*Pastanica sativa*), of St. John's bread (*Ceratonia Siliqua*); the fruit of the common Arbutus (*Arbutus Unedo*), and other sweet-tasted fruits; the roots of the Turnip (*Brassica Rapa*), of the Carrot (*Daucus Carota*), of Parsley (*Apium petroselinum*), the flower of the Euxine Rhododendron (*Rhododendron ponticum*), and from the nectarium of most other flowers.

The nutritive properties of sugar are well known. At the time the British market was over-stocked with this article from the West India islands, proposals were made for applying it as the food of cattle; experiments had been instituted, which proved that they might be fattened by it: but difficulties connected with the duties laid on sugar prevented the plan from being tried to any extent.

4. *Albumen* is a substance which has only lately been discovered in the vegetable kingdom. It abounds in the juice of the Papaw-tree (*Carica papaya*:) when the juice is boiled, the albumen falls down in a coagulated state. It is likewise found in mushrooms, and in different species of funguses.

Albumen, in its pure form, is a thick, glairy, tasteless fluid; precisely the same as the white of the egg; it is soluble in cold water; its solution, when not too diluted, is coagulated by boiling, and the albumen separates in the form of thin flakes. Albumen is likewise coagulated by acids and by alcohol: a solution of

albumen gives a precipitate when mixed with a cold solution of nutgalls. Albumen, when burnt, produces a smell of volatile alkali, and affords carbonic acid and water; it is therefore evidently principally composed of carbon, hydrogen, oxygen, and azote.

According to the experiments of Gay Lussac and Thenard, 100 parts of albumen from the white of the egg are composed of

Carbon	-	-	52·883
Oxygen	-	-	23·872
Hydrogen	-	-	7·540
Azote	-	-	15·705

This estimation would authorise the supposition that albumen is composed of 2 proportions of azote, 5 oxygen, 9 carbon, 32 hydrogen.

The principal part of the almond, and of the kernels of many other nuts, appears from the experiments of Proust to be a substance analogous to coagulated albumen.

The juice of the fruit of the Ochra (*Hibiscus esculentus*,) according to Dr. Clarke, contains a liquid albumen in such quantities, that it is employed in Dominica as a substitute for the white of eggs in clarifying the juice of the sugar-cane.

Albumen may be distinguished from other substances by its property of coagulating by the action of heat or acids, when dissolved in water. According to Dr. Bostock, when the solution contains only one grain of albumen to 1000 grains of water, it becomes cloudy by being heated.

Albumen is a substance common to the animal as well as to the vegetable kingdom, and much more abundant in the former.

5. *Gluten* may be obtained from wheaten flour by the following process: — the flour is to be made into a

paste, which is to be cautiously washed, by kneading it under a small stream of water, till the water has carried off from it all the starch; what remains is gluten. It is a tenacious, ductile, elastic substance. It has no taste. By exposure to air, it becomes of a brown colour. It is very slightly soluble in cold water; but not soluble in alcohol. When a solution of it in water is heated, the gluten separates in the form of yellow flakes; in this respect it agrees with albumen, but differs from it in being infinitely less soluble in water. The solution of albumen does not coagulate when it contains much less than 1000 parts of albumen; but it appears that gluten requires more than 1000 parts of cold water for its solution.

Gluten, when burnt, affords similar products to albumen, and probably differs very little from it in composition. Gluten is found in a great number of plants: Proust discovered it in acorns, chesnuts, horse-chesnuts, apples and quinces; barley, rye, peas, and beans; likewise in the leaves of rue, cabbage, cresses, hemlock, borage, saffron, in the berries of the elder, and in the grape. Gluten appears to be one of the most nutritive of the vegetable substances; and wheat seems to owe its superiority to other grain from the circumstance of its containing it in larger quantities.

6. *Gum elastic* or *Caoutchouc* is procured from the juice of a tree which grows in the Brazils, called Hævea. When the tree is punctured, a milky juice exudes from it, which gradually deposits a solid substance; and this is gum elastic.

Gum elastic is pliable and soft like leather, and becomes softer when heated. In its pure state it is white; its specific gravity is 9335. It is combustible, and burns with a white flame, throwing off a dense

smoke, with a very disagreeable smell. It is insoluble in water and in alcohol; it is soluble in ether, volatile oils, and in petroleum, and may be procured from ether in an unaltered state by evaporating its solution in that liquid. Gum elastic seems to exist in a great variety of plants: amongst them are, *Jatropha elastica, Ficus indica, Artocarpus integrifolia,* and *Urceola elastica.*

Bird-lime, a substance which may be procured from the holly, is very analogous to gum elastic in its properties. Species of gum elastic may be obtained from the misletoe, from gum-mastic, opium, and from the berries of the *Smilax caduca,* in which last plant it has been lately discovered by Dr. Barton.

Gum elastic, when distilled, affords volatile alkali, water, hydrogen, and carbon, in different combinations. It therefore consists principally of azote, hydrogen, oxygen, and carbon; but the proportions in which they are combined have not yet been ascertained. Gum elastic is an indigestible substance, not fitted for the food of animals; its uses in the arts are well known.

7. *Extract* or *the extractive principle,* exists in almost all plants. It may be procured in a state of tolerable purity from saffron, by merely infusing it in water, and evaporating the solution. It may likewise be obtained from catechu, or *Terra japonica,* a substance brought from India. This substance consists principally of astringent matter, and extract; by the action of water upon it, the astringent matter is first dissolved, and may be separated from the extract. Extract is always more or less coloured: it is soluble in alcohol and water, but not soluble in ether. It unites with alumina, when that earth is boiled in a solution of extract; and it

is precipitated by the salts of alumina, and by many metallic solutions, particularly the solution of muriate of tin.

From the products of its distillation, it seems to be composed principally of hydrogen, oxygen, carbon, and a little azote.

There appears to be almost as many varieties of extract as there are species of plants. The difference of their properties probably in many cases depends upon their being combined with small quantities of other vegetable principles, or to their containing different saline, alkaline, acid, or earthy ingredients. Many dyeing substances seem to be of the nature of extractive principle; such as the red colouring matter of madder, and the yellow dye procured from weld.

Extract has a strong attraction for the fibres of cotton or linen, and combines with these substances when they are boiled in a solution of it. The combination is made stronger by the intervention of mordants, which are earthy or metallic combinations that unite to the cloth, and enable the colouring matter to adhere more strongly to its fibres.

Extract, in its pure form, cannot be used as an article of food; but it is probably nutritive when united to starch, mucilage, or sugar.

8. *Tannin*, or the tanning principle, may be procured by the action of a small quantity of cold water on bruised grape-seeds, or pounded gall-nuts; and by the evaporation of the solution to dryness. It appears as a yellow substance, possessed of a highly astringent taste. It is difficult of combustion. It is very soluble, both in water and alcohol, but insoluble in ether. When a solution of glue, or isinglass (*gelatine*,) is mixed with an aqueous solution of tannin,

the two substances, *i. e.* the animal and vegetable matters, fall down in combination, and form an insoluble precipitate.

When tannin is distilled in close vessels, the principal products are charcoal, carbonic acid, and inflammable gases, with a minute quantity of volatile alkali. Hence its elements seem the same as those of extract, but probably in different proportions. The characteristic property of tannin is its action upon solutions of isinglass or jelly; this particularly distinguishes it from extract, with which it agrees in most other chemical qualities.

There are many varieties of tannin, which probably owe the difference of their properties to combinations with other principles, especially extract, from which it is not easy to free tannin. The purest species of tannin is that obtained from the seeds of the grape; this forms a white precipitate, with solution of isinglass. The tannin from gall-nuts resembles it in its properties. That from sumach affords a yellow precipitate, that from kino a rose-coloured, that from catechu a fawn-coloured one. The colouring matter of Brazil wood, which M. Chevreul considers as a peculiar principle, and which he has called *Hematine,* differs from other species of tannin, in affording a precipitate with gelatine, which is soluble in abundance of hot water. Its taste is much sweeter than that of the other varieties of tannin, and it may perhaps be regarded as a substance intermediate between tannin and extract.

Tannin is not a nutritive substance, but it is of great importance in its application to the art of tanning. Skin consists almost entirely of jelly or *gelatine,* in an organized state, and is soluble by the long-continued action of boiling water. When skin is exposed to

solutions containing tannin, it slowly combines with that principle; its fibrous texture and coherence are preserved; it is rendered perfectly insoluble in water, and it is no longer liable to putrefaction: in short, it becomes a substance in chemical composition precisely analogous to that furnished by the solution of jelly and the solution of tannin.

In general, in this country, the bark of the oak is used for affording tannin in the manufacture of leather: but the barks of some other trees, particularly the Spanish chesnut, have lately come into use. The following table will give a general idea of the relative value of different species of barks. It is founded on the result of experiments made by myself.

Table of Numbers exhibiting the quantity of Tannin afforded by 480lbs. of different Barks, which express nearly their relative Values.

	lb.
Average of entire Bark of middle-sized Oak, cut in spring -	29
.. .. of Spanish Chesnut - - -	21
.. .. of Leicester Willow, large size -	33
.. .. of Elm - - - - - -	13
.. .. of Common Willow, large - -	11
.. .. of Ash - - - - - -	16
.. .. of Beech - - - - - -	10
.. .. of Horse Chesnut - - -	9
.. .. of Sycamore - - - -	11
.. .. of Lombardy Poplar - - -	15
.. .. of Birch - - - - - -	8
.. .. of Hazel - - - - - -	14
.. .. of Black Thorn - - - -	16
.. .. of Coppice Oak - - - -	32
.. .. of Oak, cut in autumn - - -	21
.. .. of Larch, cut in autumn - -	8
White interior cortical layers of Oak Bark - - -	72

The quantity of the tannin principle in barks differs in different seasons; when the spring has been very cold the quantity is smallest. On an average, 4 or 5 lbs. of good oak bark are required to form 1 lb. of leather. The inner cortical layers in all barks contain

the largest quantity of tannin. Barks contain the greatest proportion of tannin at the time the buds begin to open—the smallest quantity in winter.

The extractive or colouring matters found in barks, or in substances used in tanning, influence the quality of leather. Thus skin tanned with gall-nuts is much paler than skin tanned with oak bark, which contains a brown extractive matter. Leather made from catechu is of a reddish tint. It is probable that in the process of tanning, the matter of skin and the tanning principle first enter into union, and that the leather, at the moment of its formation, unites to the extractive matter.

In general, skins in being converted into leather increase in weight about one-third; * and the operation is most perfect when they are tanned slowly. When skins are introduced into very strong infusions of tannin, the exterior parts immediately combine with that principle, and defend the interior parts from the action of the solution: such leather is liable to crack and to decay by the action of water.

The precipitates obtained from infusions containing tannin by isinglass, when dried, contain at a medium rate about 40 per cent. of vegetable matter. It is easy to obtain the comparative value of different substances for the use of the tanner, by comparing the quantities of precipitate afforded by infusions of given weights mixed with solutions of glue or isinglass.

To make experiments of this kind, an ounce, or 180 grains of the vegetable substance, in coarse powder, should be acted upon by half a pint of boiling water. The mixture should be frequently stirred, and suffered

* This estimation must be considered as applying to *dry* skin and *dry* leather.

to stand twenty-four hours; the fluid should then be passed through a fine linen cloth, and mixed with an equal quantity of solution of gelatine, made by dissolving glue, jelly, or isinglass in hot water, in the proportion of a drachm of glue or isinglass, or six table-spoonfuls of jelly, to a pint of water. The precipitate should be collected by passing the mixture of the solution and infusion through folds of blotting-paper, and the paper exposed to the air till its contents are quite dry. If pieces of paper of equal weights are used, in cases in which different vegetable substances are employed, the difference of the weights of the papers, when dried, will indicate with tolerable accuracy the quantities of tannin contained by the substances, and their relative value, for the purposes of manufacture. Four-tenths of the increase of weight, in grains, must be taken, which will be in relation to the weights in the table.

Besides the barks already mentioned, there are a number of others which contain the tanning principle. Few barks, indeed, are entirely free from it. It is likewise found in the wood and leaves of a number of trees and shrubs, and is one of the most generally diffused of the vegetable principles.

A substance very similar to tannin has been formed by Mr. Hatchett, by the action of heated diluted nitric acid on charcoal, and evaporation of the mixture to dryness. From 100 grains of charcoal Mr. Hatchett obtained 120 grains of artificial tannin, which, like natural tannin, possessed the property of rendering skin insoluble in water.

Both natural and artificial tannin form compounds with the alkalies and the alkaline earths; and these compounds are not decomposable by skin. The attempts

that have been made to render oak bark more efficient as a tanning material by infusion in lime water, are consequently founded on erroneous principles. Lime forms with tannin a compound not soluble in water.

The acids unite to tannin, and produce compounds that are more or less soluble in water. It is probable that in some vegetable substances tannin exists combined with alkaline or earthy matter; and such substances will be rendered more efficacious for the use of the tanner by the action of diluted acids.

9. *Indigo* may be procured from woad (*Isatis tinctoria*), by digesting alcohol on it, and evaporating the solution. White crystalline grains are obtained, which gradually become blue by the action of the atmosphere: these grains are the substance in question.

The indigo of commerce is principally brought from America. It is procured from the *Indigofera argentea*, or wild indigo, the *Indigofera disperma*, or Guatimala indigo, and the *Indigofera tinctoria*, or French indigo. It is prepared by fermenting the leaves of those trees in water. Indigo, in its common form, appears as a fine deep blue powder. It is insoluble in water, and but slightly soluble in alcohol: its true solvent is sulphuric acid: 8 parts of sulphuric acid dissolve 1 part of indigo; and the solution diluted with water forms a very fine blue dye.

Indigo, by its distillation, affords carbonic acid gas, water, charcoal, ammonia, and some oily and acid matter; the charcoal is in very large proportion. Pure indigo, therefore, most probably consists of carbon, hydrogen, oxygen, and azote.

Indigo owes its blue colour to combination with oxy-

gen. For the uses of the dyers, it is partly deprived of oxygen, by digestiug it with orpiment and lime water, when it becomes soluble in the lime water, and of a greenish colour. Cloths steeped in this solution combine with the indigo; they are green when taken out of the liquor, but become blue by absorbing oxygen when exposed to air.

Indigo is one of the most valuable and most extensively used of the dyeing materials.

10. There are a number of colouring principles found in different vegetable productions, the properties of which are less marked than those of indigo, and the separation more difficult. The colouring matters of carthamus and madder are the most fixed amongst the red vegetable colours. A number of vegetable substances are rendered red by the action of acids, and green by that of alkalies. They all seem to be composed of different proportions of hydrogen, oxygen, and carbon; but are so liable to change, that few distinct experiments have been made upon their nature. In dyeing, they are usually applied to cloths prepared for receiving them by combination with certain saline or metallic preparations called mordants; and, in consequence of the triple union formed between the cloth, the mordant, and the colouring matter, the tint is modified, or changed, and rendered more permanent.

11. The *bitter principle* is very extensively diffused in the vegetable kingdom; it is found abundantly in the hop (*Humulus lupulus*), in the common Broom (*Spartium scoparium*), in the Chamomile (*Anthemis nobilis*), and in *Quassia amara* and *excelsa*. It is obtained from those substances by the action of water or alcohol, and evaporation. It is usually of a pale yellow colour; its taste is intensely bitter. It is very soluble, both in water

and alcohol; and has little or no action on alkaline, acid, saline, or metallic solutions.

An artificial substance, similar to the bitter principle, has been obtained by digesting diluted nitric acid on silk, indigo, and the wood of the white willow. This substance has the property of dyeing cloth of a bright yellow colour; it differs from the natural bitter principle in its power of combining with the alkalies; in union with the fixed alkalies, it constitutes crystallised bodies, which have the property of detonating by heat or percussion.

The natural bitter principle is of great importance in the art of brewing; it checks fermentation, and preserves fermented liquors; it is likewise used in medicine.

The bitter principle, like the narcotic principle, appears to consist principally of carbon, hydrogen, and oxygen, with a little azote.

12. *Wax* is found in a number of vegetables; it is procured in abundance from the berries of the Wax Myrtle (*Myrica cerifera*); it may be likewise obtained from the leaves of many trees, in its pure state it is white. Its specific gravity is ·9662, it melts at 155 degrees; it is dissolved by boiling alcohol; but it is not acted upon by cold alcohol; it is insoluble in water: its properties, as a combustible body, are well known.

The wax of the vegetable kingdom seems to be precisely of the same nature as that afforded by the bee.

From the experiments of MM. Gay Lussac and Thenard, it appears that 100 parts of wax consist of

Carbon - - - -	1·784
Oxygen - - - -	5·544
Hydrogen - - - -	12·672

Or of

Carbon - - - -	81·784
Oxygen and hydrogen in the proportions necessary to form water - -	6·300
Hydrogen - - - -	11·916

Which agrees very nearly with 37 proportions of hydrogen, 21 of charcoal, 1 of oxygen.

13. *Resin* is very common in the vegetable kingdom. One of the most usual species is that afforded by the different kinds of fir. When a portion of the bark is removed from the fir-tree in spring, a matter exudes, which is called turpentine; by heating this turpentine gently, a volatile oil rises from it, and a more fixed substance remains: this substance is resin.

The resin of the fir is the substance commonly known by the name of rosin; its properties are well known. Its specific gravity is 1072. It melts readily, burns with a yellow light, throwing off much smoke. Resin is insoluble in water, either hot or cold; but very soluble in alcohol. When a solution of resin in alcohol is mixed with water, the solution becomes milky; the resin is deposited by the stronger attraction of the water for the alcohol.

Resins are obtained from many other species of trees. *Mastich* from the *Pistacia lentiscus*, *Elemi* from the *Amyris elemifera*, *Copal* from the *Rhus copallinum*, *Sandarach* from the common juniper. Of these resins copal is the most peculiar. It is the most difficultly dissolved in alcohol; and for this purpose must be exposed to that substance in vapour; or the alcohol employed must hold camphor in solution. According to Gay Lussac and Thernard,

100 parts of common resin contain

Carbon - - - -	75·944
Oxygen - - - -	13·337
Hydrogen - - - -	10·719

Or of

Carbon - - - -	75·944
Oxygen and hydrogen in the proportions necessary to form water - -	15·156
Hydrogen in excess - -	8·900

According to the same chemists, 100 parts of copal consist of

Carbon - - - -	76·811
Oxygen - - - -	10·606
Hydrogen - - - -	12·583

Or,

Carbon - - - -	76·11
Water or its elements - -	12·052
Hydrogen - - - -	11·137

From these results, if resin be a definite compound, it may be supposed to consist of 8 proportions of carbon, 12 of hydrogen, and 1 of oxygen.

Resins are used for a variety of purposes. Tar and pitch principally consist of resin, in a partially decomposed state. Tar is made by the slow combustion of the fir; and pitch by the evaporation of the more volatile parts of tar. Resins are employed as varnishes, and for these purposes are dissolved in alcohol or oils. Copal forms one of the finest. It may be made by boiling it in powder with oil of rosemary, and then adding alcohol to the solution.

14. *Camphor* is produced by distilling the wood of the Camphor-tree (*Laurus camphora*), which grows in Japan. It is a very volatile body, and may be purified

by distillation. Camphor is a white, brittle, semitransparent substance, having a peculiar odour, and a strong acrid taste. It is very slightly soluble in water; more than 100,000 parts of water are required to dissolve 1 part of camphor. It is very soluble in alcohol; and by adding water in small quantities at a time to the solution of camphor in alcohol, the camphor separates in a crystallised form. It is soluble in nitric acid, and is separated from it by water.

Camphor is very inflammable; it burns with a bright flame, and throws off a great quantity of carbonaceous matter. It forms, in combustion, water, carbonic acid, and a peculiar acid called *camphoric* acid. No accurate analysis has been made of camphor, but it seems to approach to the resins in its composition; and consists of carbon, hydrogen, and oxygen.

Camphor exists in other plants besides the *Laurus camphora*. It is procured from species of the Laurus growing in Sumatra, Borneo, and other of the East Indian isles. It has been obtained from Thyme (*Thymus serpyllum*,) Marjoram (*Origanum majorana*,) Ginger tree (*Amomum zingiber*), Sage (*Salvia officinalis*). Many volatile oils yield camphor by being merely exposed to the air.

An artificial substance very similar to camphor has been formed by M. Kind, by saturating oil of turpentine with muriatic acid gas (the gaseous substance procured from common salt by the action of sulphuric acid.) The camphor procured in well-conducted experiments amounts to half of the oil of turpentine used. It agrees with common camphor in most of its sensible properties; but differs materially in its chemical qualities and composition. It is not soluble without decomposition in nitric acid. From the experiments of

Gehlen, it appears to consist of the elements of oil of turpentine, carbon, hydrogen, and oxygen, united to the elements of muriatic gas, chlorine and hydrogen.

From the analogy of artificial to natural camphor, it does not appear improbable that natural camphor may be a secondary vegetable compound, consisting of camphoric acid and volatile oil. Camphor is used medicinally, but it has no other application.

15. *Fixed oil* is obtained by expression from seeds and fruits; the olive, the almond, linseed, and rapeseed, afford the most common vegetable fixed oils. The properties of fixed oils are well known. Their specific gravity is less than that of water; that of olive and of rape-seed oil is ·913; that of linseed and almond oil ·932; that of palm oil ·968; that of walnut and beech-mast oil ·923. Many of the fixed oils congeal at a lower temperature than that at which water freezes. They all require for their evaporation a higher temperature than that at which water boils. The products of the combustion of oil are water and carbonic acid gas.

From the experiments of Gay Lussac and Thenard, it appears that olive oil contains, in 100 parts,

Carbon	-	-	-	77·213
Oxygen	-	-	-	9·427
Hydrogen	-	-	-	13·360

This estimation is a near approximation to 11 proportions of carbon, 20 hydrogen, and 1 oxygen.

The following is a list of fixed oils, and of the trees that afford them.

Olive oil, from the Olive tree (*Olea europea*), Linseed oil, from the common and perennial Flax (*Linum usitatissimum et perenne*), Nut oil, from the Hazel nut (*Cory-*

lus Avellana), Walnut (*Juglans regia*), Hemp oil, from the Hemp (*Cannabis sativa*), Almond oil, from the sweet Almond (*Amygdalus communis*), Beech oil, from the common Beech (*Fagus sylvatica*), Rape-seed oil, from the Rapes (*Brassica Napus et campestris*), Poppy oil, from the Poppy (*Papaver somniferum*), oil of Sesamum, from the Sesamum (*Sesamum orientale*), Cucumber oil, from the gourds (*Cucurbita Pepo et Melopepo*), oil of Mustard, from the Mustard (*Sinapis nigra et arvensis*), oil of Sunflower, from the annual and perennial Sunflower (*Helianthus annuus et perennis*), Castor oil, from the Palma Christi (*Ricinus communis*), Tobacco-seed oil, from the Tobacco (*Nicotiana Tabacum et rustica*), Plum kernel oil from the Plum tree (*Prunus domestica*), Grape-seed oil, from the Vine (*Vitis vinifera*), Butter of cacoa, from the Cacoa tree (*Theobroma Cacao*), Laurel oil, from the sweet Bay tree (*Laurus nobilis*).

The fixed oils are very nutritive substances: they are of great importance in their applications to the purposes of life. Fixed oil, in combination with soda, forms the finest kind of hard soap. The fixed oils are used extensively in the mechanical arts, and for the preparation of pigments and varnishes.

16. *Volatile oil,* likewise called *essential oil,* differs from fixed oil, in being capable of evaporation by a much lower degree of heat, in being soluble in alcohol, and in possessing a very slight degree of solubility in water.

There is a great number of volatile oils, distinguished by their smell, their taste, their specific gravity, and other sensible qualities. A strong and peculiar odour may, however, be considered as the great characteristic of each species: the volatile oils inflame with more facility than the fixed oils, and afford, by their com-

bustion, different proportions of the same substances, water, carbonic acid, and carbon.

The following specific gravities of different volatile oils were ascertained by Dr. Lewis:—

Oil of Sassafras	1094	Oil of Tansy	946
—— Cinnamon	1035	—— Caraway	940
—— Cloves	1034	—— Origanum	940
—— Fennel	997	—— Spike	936
—— Dill	994	—— Rosemary	934
—— Penny Royal	978	—— Juniper	911
—— Cumin	975	—— Oranges	888
—— Mint	975	—— Turpentine	792
—— Nutmegs	948		

The peculiar odours of plants seem, in almost all all cases, to depend upon the peculiar volatile oils they contain. All the perfumed distilled waters owe their peculiar properties to the volatile oils they hold in solution. By collecting the aromatic oils, the fragrance of flowers, so fugitive in the common course of nature, is as it were embodied and made permanent.

It cannot be doubted that the volatile oils consist of carbon, hydrogen, and oxygen; but no accurate experiments have as yet been made on the proportions in which these elements are combined.

The volatile oils have never been used as articles of food; many of them are employed in the arts, in the manufacture of pigments and varnishes; but their most extensive application is as perfumes.

17. *Woody fibre* is procured from wood, bark, leaves or flowers of trees, by exposing them to the repeated action of boiling water and boiling alcohol. It is the insoluble matter that remains, and is the basis of the solid organized parts of plants. There are as many

varieties of woody fibre as there are plants and organs of plants; but they are all distinguished by their fibrous texture, and their insolubility.

Woody fibre burns with a yellow flame, and produces water and carbonic acid in burning. When it is distilled in close vessels, it yields a considerable residuum of charcoal. It is from woody fibre, indeed, that charcoal is procured for the purposes of life.

The following table contains the results of experiments made by Mr. Mushet, on the quantity of charcoal afforded by different wood:—

100 parts of	Lignum Vitæ - -	26·8 of charcoal.
———	Mahogany - -	25·4
———	Laburnum - -	24·5
———	Chesnut - - -	23·2
———	Oak - - - -	22·6
———	American black Beech -	21·4
———	Walnut - - -	20.6
———	Holly - - - -	19·9
———	Beech - - -	19·9
———	American Maple -	19·9
———	Elm - - - -	19·5
———	Norway Pine - -	19·2
———	Sallow - - -	18·4
———	Ash - - - -	17·9
———	Birch - - - -	17·4
———	Scottish Fir - -	16·4

MM. Gay Lussac and Thenard have concluded from their experiments on the wood of the oak and the beech, that 100 parts of the first contain:—

Of Carbon - - - -	52·53
— Oxygen - - - -	41·78
— Hydrogen - - -	5·69

and 100 parts of the second:—

Of Carbon - - - -	51·45
— Oxygen - - - -	42·73
— Hydrogen - - -	5·82

Supposing woody fibre to be a definitive compound, these estimations lead to the conclusion, that it consists of 5 proportions of carbon, 3 of oxygen, and 6 of hydrogen; or 57 carbon, 45 oxygen, and 6 hydrogen.

It will be unnecessary to speak of the applications of woody fibre. The different uses of the woods, cotton, linen, the barks of trees, are sufficiently known. Woody fibre appears to be an indigestible substance.

18. The acids found in the vegetable kingdom are numerous; the true vegetable acids which exist ready formed in the juices or organs of plants, are the *oxalic*, *citric*, *tartaric*, *benzoic*, *acetic*, *meconic*, *malic*, *gallic*, and *prussic* acid.

All these acids, except the acetic, malic, and prussic acids, are white crystallized bodies. The acetic, malic, and prussic acids, have been obtained only in the fluid state; they are all more or less soluble in water: all have a sour taste, except the gallic and prussic acids; of which the first has an astringent taste, and the latter a taste like that of bitter almonds. The meconic acid exists in opium.

The oxalic acid exists, uncombined, in the liquor which exudes from the Chich pea (*Cicer arietinum*), and may be procured from wood Sorrel (*Oxalis Acetosella*), common sorrel, and other species of Rumex; and from the *Geranium acidum*. Oxalic acid is easily discovered and distinguished from other acids, by its property of decomposing all calcareous salts, and forming with lime a salt insoluble in water; and by its crystallizing in four-sided prisms.

The citric acid is the peculiar acid existing in the juice of lemons and oranges. It may likewise be obtained from the cranberry, whortleberry, and hip.

Citric acid is distinguished by its forming a salt insoluble in water with lime; but decomposable by the mineral acids.

The tartaric acid may be obtained from the juice of mulberries and grapes; and likewise from the pulp of the tamarind. It is characterized by its property of forming a difficultly-soluble salt with potassa, and an insoluble salt decomposable by the mineral acids with lime.

Benzoic acid may be procured from several resinous substances by distillation: from benzoin, storax, and balsam of Tolu. It is distinguished from the other acids by its aromatic odour, and by its extreme volatility.

Malic acid may be obtained from the juice of apples, barberries, plums, elderberries, currants, strawberries, and raspberries. It forms a soluble salt with lime; and is easily distinguished by this test, from the acids already named.

Acetic acid, or vinegar, may be obtained from the sap of different trees. It is distinguished from malic acid, by its peculiar odour; and from the other vegetable acids, by forming soluble salts with the alkalies and earths.

Gallic acid may be obtained, by gently and gradually heating powdered gall-nuts, and receiving the volatile matter in a cool vessel. A number of white crystals will appear, which are distinguished by their property of rendering solutions of iron deep purple.

The vegetable prussic acid, is procured by distilling laurel leaves, or the kernels of the peach, and cherry, or bitter almonds. It is characterized by its property of forming a bluish-green precipitate, when a little alkali is added to it, and it is poured into solutions containing

iron. It is very analogous in its properties to the prussic acid obtained from animal substances; or by passing ammonia over heated charcoal: but this last body forms, with the red oxide of iron, the deep bright blue substance called Prussian blue.

Some other vegetable acids have been found in the products of plants; the morolyxic acid in a saline exudation from the white mulberry tree, and the kinic acid in a salt afforded by Peruvian bark; but these two bodies have as yet been discovered in no other cases. The igasuric acid is so named by its discoverers, MM. Pelletier and Caventou: and the boletic, nanceic, fungic, and ellagic acids, have been described by M. Braconnot; but their properties are too little interesting to the agriculturist, to insert a description in this place. The phosphoric acid is found free in the onion; and the phosphoric, sulphuric, muriatic, and nitric acids, exist in many saline compounds in the vegetable kingdom; but they cannot with propriety be considered as vegetable products. Other acids are produced during the combustion of vegetable compounds, or by the action of nitric acid upon them; they are the camphoric acid, the mucous or saclactic acid, and the suberic acid; the first of which is procured from camphor; the second from gum or mucilage; and the third from cork, by the action of nitric acid.

From the experiments that have been made upon the vegetable acids, it appears that all of them, except the prussic acid, are constituted by different proportions of carbon, hydrogen, and oxygen: the prussic acid consists of carbon, azote, and hydrogen, with a little oxygen. The gallic acid contains more carbon than any of the other vegetable acids.

The following estimates of the composition of some

of the vegetable acids have been made by Gay Lussac and Thenard: —

100 parts of oxalic acid contain:

Carbon	- -	26·566
Hydrogen	- -	2·745
Oxygen	- -	70·689

100 parts of tartaric acid contain:

Carbon	- -	24·050
Hydrogen	- -	6·629
Oxygen	- -	69·321

Ditto citric acid:

Carbon	- -	33·811
Hydrogen	- -	6·330
Oxygen	- -	59·859

100 parts of acetic acid:

Carbon	- -	50·224
Hydrogen	- -	5·629
Oxygen	- -	44·147

Ditto mucous or saclactic acid:

Carbon	- -	33·69
Hydrogen	- -	3·62
Oxygen	- -	62·69

These estimations agree nearly with the following definite proportions. In oxalic acid, 7 proportions of carbon, 8 of hydrogen, and 15 oxygen,; in tartaric acid, 8 carbon, 28 hydrogen, 18 oxygen; in citric acid, 3 carbon, 6 hydrogen, 4 oxygen; in acetic acid, 18 carbon, 22 hydrogen, 12 oxygen; in mucous acid, 6 carbon, 7 hydrogen, 8 oxygen.

The applications of the vegetable acids are well known. The acetic and citric acids are extensively used. The agreeable taste and wholesomeness of various vegetable substances used as food materially depend upon the vegetable acid they contain.

19. It is uncertain whether ammonia or the volatile alkali exists ready formed in plants: but it is evolved rom many of them by the action of lime or fixed alkali, assisted by a gentle heat; though it may be always imagined to be generated during the process by the combination of azote and carbon. The ingenious researches of M. Serturner, followed by those of other chemists, have made us acquainted with the alkaline properties of several compound vegetable substances, which were not suspected to belong to this class of bodies, such as morphina, strychnina, brucina, picrotoxina, delphina; these compounds, which are found respectively in opium, nux vomica, Brucea antidysenterica, cocculus indicus, and Delphinium Staphisagria, agree with alkalies in their effects upon vegetable colours, and in combining with acids, into peculiar neutro-saline compounds. They form the narcotic or poisonous principles of the plants in which they are found, and probably many more of them will be discovered. They are not very interesting to the agriculturist, except in this point of view, *that possibly many noxious vegetable substances may be rendered useful as the food of cattle*, by extracting their noxious principles by means of acids; and this is a subject well worthy of experimental investigation.

Fixed alkali may be obtained in aqueous solution from most plants by burning them, and treating the ashes with quick-lime and water. The vegetable alkali, or potassa, is the common alkali in the vegetable kingdom. This substance, in its pure state, is white and semi-transparent, requiring a strong heat for its fusion, and possessed of a highly caustic taste. In the matter usually called pure potassa by chemists, it exists, combined with water; and in that commonly called pearl-

ashes, or pot-ashes in commerce, it is combined with a small quantity of carbonic acid. Potassa in its uncombined state, as has been mentioned, page 217, consists of the highly inflammable metal potassium and oxygen, one proportion of each.

Soda, or the mineral alkali, is found in some plants that grow near the sea; and is obtained combined with water, or carbonic acid in the same manner as potassa; and consists of one proportion of sodium, and two proportions of oxygen. In its properties it is very similar to potassa; but it may be easily distinguished from it by this character: it forms a hard soap with oil: potassa forms a soft soap.

Pearl ashes, and barilla and kelp, or the impure soda obtained from the ashes of marine plants, are very valuable in commerce, principally on account of their uses in the manufacture of glass and soap. Glass is made from fixed alkali, flint, and certain metallic substances.

To know whether a vegetable yields alkali, it should be burnt, and the ashes washed with a small quantity of water. If the water, after being for some time exposed to the air, reddens paper tinged with turmeric, or renders vegetable blues green, it contains alkali.

To ascertain the relative quantities of pot-ashes afforded by different plants, equal weights of them should be burnt: the ashes washed in twice their volume of water: the washings should be passed through blotting paper, and evaporated to dryness. The relative weights of the salt obtained will indicate very nearly the relative quantities of alkali they contain.

The value of marine plants in producing soda may be estimated in the same manner, with sufficient correctness for all commercial purposes.

Herbs, in general, furnish four or five times, and shrubs two or three times, as much pot-ashes as trees. The leaves produce more than the branches, and the branches more than the trunk. Vegetables burnt in a green state produce more ashes than in a dry state.

The following table* contains a statement of the quantity of pot-ashes afforded by some common trees and plants:—

10,000 parts of	Oak	15
———	Elm	39
———	Beech	12
———	Vine	55
———	Poplar	7
———	Thistle	53
———	Fern	62
———	Cow Thistle	196
———	Wormwood	730
———	Vetches	275
———	Beans	200
———	Fumitory	760

The earths found in plants are four; silica or the earth of flints, alumina or pure clay, lime, and magnesia. They are procured by incineration. The lime is usually combined with carbonic acid. This substance and silica are much more common in the vegetable kingdom than magnesia, and magnesia more common than alumina. The earths form a principal part of the matter insoluble in water, afforded by the ashes of plants. The silica is known by not being dissolved by acids; the calcareous earth, unless the ashes have been very intensely ignited, dissolves with effervescence in muriatic acid. Magnesia forms a soluble

* It is founded upon the experiments of Kirwan, Vauquelin, and Pertuis.

and crystallizable salt, and lime a difficultly soluble one with sulphuric acid. Alumina is distinguished from the other earths by being acted upon very slowly by acids; and in forming salts very soluble in water, and difficult of crystallization with them.

The earths appear to be compounds of the peculiar metals mentioned in page 218, and oxygen, one proportion of each.

The earths afforded by plants are applied to no uses of common life; and there are few cases in which the knowledge of their nature can be of importance, or afford interest to the farmer.

The only *metallic oxides* found in plants, are those of iron and manganesum: they are detected in the ashes of plants; but in very minute quantities only. When the ashes of plants are reddish brown, they abound in oxides of iron; when black or purple, in oxide of manganesum; when these colours are mixed, they contain both substances.

The saline compounds contained in plants, or afforded by their incineration, are very various. The sulphuric acid combined with potassa, or sulphate of potassa, is one of the most usual. Common salt is likewise very often found in the ashes of plants; likewise phosphate of lime, which is insoluble in water, but soluble in muriatic acid. Compounds of the nitric, muriatic, sulphuric, and phosphoric acids, with alkalies and earths, exist in the sap of many plants, or are afforded by their evaporation and incineration. The salts of potassa are distinguished from those of soda by their producing a precipitate in solutions of platina: those of lime are characterized by the cloudiness they occasion in solutions containing oxalic acid; those of magnesia, by being rendered cloudy by solutions of

ammonia. Sulphuric acid is detected in salts by the dense white precipitate it forms in solutions of baryta. Muriatic acid by the cloudiness it communicates to solution of nitrate of silver; and when salts contain nitric acid, they produce scintillations by being thrown upon burning coals.

As no applications have been made of any of the neutral salts or analagous compounds found in plants, in a separate state, it will be useless to describe them individually. The following tables are given from M. Th. de Saussure's Researches on Vegetation, and contain results obtained by that philosopher. They exhibit the quantities of soluble salts, metallic oxides, and earths afforded by the ashes of different plants:—

					Constituents of 100 parts of Ashes.					
	Names of Plants.	Ashes from 1000 parts of the Plant green.	Ditto dry.	Water from 1000 parts of the Plant green.	Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
1	Leaves of oak (*Querous Robur*), May 10. -	13	53	745	47	24	0.12	3	0·64	25·24
2	Ditto, Sept. 27. - -	24	55	549	17	18·25	23	14·5	1·75	25·5
3	Wood of young oak, May 10. - - - - -	—	4	—	26	28·5	12·25	0·12	1	32·38
4	Bark of ditto - -	—	60	—	7	4·5	63·25	0·25	1·75	22·75
5	Entire wood of oak -	—	2	—	38·6	4·5	32	2	2·25	20·65
6	Alburnum of ditto -	—	—	—	32	24	11	7·5	2	23·5
7	Bark of ditto - -	—	60	—	7	3	66	1·5	2	21·5
8	Cortical layers of ditto -	—	73	—	7	3·75	65	0·5	1	22.75
9	Extract of wood of ditto	—	61	—	51					
10	Soil from wood of ditto	—	41	—	24	10·5	10	32	14	8·5
11	Extract from ditto -	—	111	—	66					
12	Leaves of the poplar (*Populus nigra*), May 26. -	23	66	652	36	13	29	5	1·25	15·75
13	Ditto, Sept. 12. - -	41	93	565	26	7	36	11·5	1·5	18
14	Wood of ditto, Sept. 12.	—	8	26	—	16·75	27	3·3	1·5	24·5
15	Bark of ditto - -	—	72	—	6	5·3	60	4	1·5	23·2
16	Leaves of hazel (*Corylus Avellana*), May 1. -	—	61	—	26	23·3	22	2·5	1·5	24·7
17	Ditto washed in cold water - - -	—	57	—	8·2	19·5	44·1	4	2	22·2
18	Leaves of ditto, June 22.	28	62	655	22·7	14	29	11·3	1·5	21·5
19	Ditto, Sept. 20. - -	31	70	557	11	12	36	22	2	17
20	Wood of ditto, May 1. -	—	5	—	24·5	35	8	0·25	0·12	32·2
21	Bark of ditto - -	—	62	—	12·5	5·5	54	0·25	1.75	26

	Names of Plants.	Ashes from 1000 parts of the Plant green.	Ditto dry.	Water from 1000 parts of the Plant green.	Constituents of 100 parts of Ashes. Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
22	Entire wood of mulberry (*Morus nigra*), Nov. -	—	7	—	21	2·25	56	0·12	0·25	20·88
23	Alburnum of ditto -	—	13	—	26	27·25	24	1	0·25	21·5
24	Bark of ditto - -	—	89	—	7	8·5	45	15·25	1·12	23·13
25	Cortical layers of ditto -	—	88	—	10	16·5	48	0·12	1	23.38
26	Entire wood of hornbeam (*Carpinus Betulus*), Nov. - - -	4	6	346	22	23	26	0·12	2·25	26·63
27	Alburnum of ditto -	4	7	390	18	36	15	1	1	29
28	Bark of ditto - -	88	134	346	4·5	4·5	59	1·5	0.12	30·38
29	Wood of horse chestnut (*Æsculus Hippocastanum*), May 10. -	—	35	—	9·5					
20	Leaves of ditto, May 10.	16	72	782	50					
31	Leaves of ditto, July 23.	29	84	652	24					
32	Ditto, Sept. 27. - -	31	86	630	13·5					
33	Flowers of ditto, May 10.	9	71	873	50					
34	Fruit of ditto, Oct. 5. -	12	34	647	82	12	—	0·5	0·25	5·25
35	Plants of peas (*Pisum sativum*), in flower -	—	95	—	49·8	17·25	6	2·3	1	24·65
36	Plants of peas (*Pisum sativum*), in flower, ripe - - - -	—	81	—	34·25	22	14	11	2·5	17.25
37	Plants of vetches (*Vicia Faba*), before flowering, May 23. -	16	150	895	55·5	14·5	3·5	1·5	0·5	24·50
38	Ditto, in flower, June 23.	20	122	876	55·5	13·5	4·12	1·5	0·5	24·38
39	Ditto, ripe, July 23. -	—	66	—	50	17.75	4	1·75	0·5	26
40	Ditto, seeds separated -	—	115	—	42	5·75	36	1·75	1	12·9
41	Seeds of ditto - -	—	33	—	69·28	27·92	—	—	0.5	2.3
42	Ditto, in flower, raised in distilled water -	—	39	—	60·1	30	—	—	0·5	9·4
43	*Solidago vulgaris*, before flowering, May 1.	—	92	—	67.5	10·75	1·5	1·5	0·75	18·25
44	Ditto, just in flower, July 15. - - -	—	57	—	59	59	1·5	1·5	0·75	21
45	Ditto, seeds ripe, Sept. 20. - - - -	—	50	—	48	11	17·25	3·5	1·5	18·75
46	Plants of turnsol (*Helianthus annuus*), a month before flowering, June 23. - -	—	147	—	63	67	11·56	1.5	0·12	16·67
47	Ditto, in flower, July 23.	13	137	877	61	6	12·5	1·5	0·12	18·78
48	Ditto, bearing ripe seeds, Sept. 20. - - -	23	93	753	5·15	22.5	4	3·75	0·5	17·75
49	Wheat (*Triticum sativum*,) in flower -	—	—	—	43.25	12·75	0·25	32	0·5	12·25
50	Ditto, seeds ripe - -	—	—	—	11	15	0.25	54	1	18·75
51	Ditto, a month before flowering - - -	—	79	—	60	11·5	0·25	12·5	0·25	15·5
52	Ditto, in flower, June 14.	16	54	699	41	10·75	0·25	26	0·5	21·5
53	Ditto, seeds ripe - -	—	33	—	10	11·75	0·25	51	0·75	23
54	Straw of wheat - -	—	43	—	22·5	6·2	1	61·5	1	78
55	Seeds of ditto - -	—	13	—	47·16	44·5	—	0·5	0·25	7.6

	Names of Plants.	Ashes from 1000 parts of the Plant green.	Ditto dry.	Water from 1000 parts of the Plant green.	Constituents of 100 parts of Ashes. Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
56	Bran - - - - -	—	52	—	4·16	46·5	—	0·5	0·25	8·6
57	Plants of maize (*Zea Mays*), a month before flowering, June 23. -	—	122	—	69	5·75	0·25	7·5	0.25	17·25
58	Ditto, in flower, July 23.	—	81	—	69	6	0·25	7·5	0.25	17
59	Ditto, seeds ripe - -	—	46							
60	Stalks of ditto - -	—	84	—	72.45	5	1	18	0.5	3.05
61	Spikes of ditto - -	—	16							
62	Seeds of ditto - -	—	10	—	62	36	—	1	0·12	0·88
63	Chaff of barley (*Hordeum vulgare*) - -	—	42	—	20	7·75	12·5	57	0·5	2·25
64	Seeds of ditto - -	—	18	—	29	32·5	—	35.5	0·25	2·8
65	Ditto - - - - -	—	—	—	22	22	—	21	0·12	20·88
66	Oats - - - - -	—	31	—	1	24	—	60	0·25	14·75
67	Leaves of *Rhododendron ferrugineum*, raised on Jura, a lime-stone mountain, June 20. -	—	30	—	23	14	43·25	0·75	3·25	15·63
68	Leaves of ditto, raised on Breven, a granitic mountain, June 27. -	—	25	—	21·1	16·75	16·75	2	5·77	31·62
69	Branches of ditto, June 20. - - - - -	—	8	—	22·5	10	39	0·5	5.4	22·48
70	Spikes of ditto, June 27.	—	8	—	24	11·5	29	1	11	24·5
71	Leaves of fir (*Pinus Abies*), raised on Jura, June 20. - - -	—	29	—	16	12·17	43·5	2·5	1·6	24·13
72	Ditto, raised on Breven, June 27. - - -	—	29	—	15	12	29	19	5·5	19·5
73	Branches of Pine, June 20. - - - - -	—	15	—	15					
74	Whortleberry (*Vaccinium Myrtillus*), raised on Jura, Aug. 29. -	—	26	—	17	18	42	0·5	3·12	19·38
75	Ditto, raised on Breven	—	22	—	24	22	22	5	9·5	17·5

Besides the principles, the nature of which has been just discussed, others have been described by chemists as belonging to the vegetable kingdom: thus a substance, somewhat analogous to the muscular fibre of animals, has been detected by Vauquelin in the papaw; and a matter similar to animal gelatine, by Braconnot, in the mushroom; ulmin and emetine, sarcocol, nicotine, olivile, asparagine, inulin, and other bodies, are

generally described in systematic writers on chemistry as specific compounds; but it is likely that few of these bodies will retain their places as definite combinations: their existence, likewise, is extremely limited, and in this place it would be improper to dwell upon peculiarities; my object being to offer such general views of the constitution of vegetables as may be of use to the agriculturist. It is probable, from the taste of sarcocol, that it is gum combined with a little sugar. Inulin is so analogous to starch, that it may be a variety of that principle. If slight differences in chemical and physical properties be considered as sufficient to establish a difference in the species of vegetable substances, the catalogue of them might be enlarged to almost any extent. No two compounds procured from different vegetables are precisely alike; and there are even differences in the qualities of the same compound, according to the time in which it has been collected, and the manner in which it has been prepared. The great use of classification in science is to assist the memory, and it ought to be founded upon the similarity of properties which are distinct, characteristic, and invariable.

The analysis of any substance, containing mixtures of the different vegetable principles, may be made, in such a manner as is necessary for the views of the agriculturist, with facility. A given quantity, say 200 grains, of the substance, should be powdered, made into a paste or mass, with a small quantity of water, and kneaded in the hands, or rubbed in a mortar for some time under cold water: if it contain much gluten, that principle will separate in a coherent mass. After this process, whether it has afforded gluten or not, it should be kept in contact with half a pint of cold water for three or four

hours, being occasionally rubbed or agitated; the solid matter should be separated from the fluid by means of blotting-paper. The fluid should be gradually heated; if any flakes appear, they are to be separated by the same means as the solid matter in the last process, *i. e.* by filtration. The fluid is then to be evaporated to dryness. The matter obtained is to be examined by applying moist paper, tinged with red cabbage juice, or violet juice, to it; if the paper become red, it contains acid matter; if it become green, alkaline matter; and the nature of the acid or alkaline matter may be known by applying the tests described page 262. 267. 268. If the solid matter be sweet to the taste, it must be supposed to contain sugar; if bitterish, bitter principle, or extract; if astringent, tannin: and if it be nearly insipid, it must be principally gum or mucilage. To separate gum or mucilage from the other principles, alcohol must be boiled upon the solid matter, which will dissolve the sugar and the extract, and leave the mucilage; the weight of which may be ascertained.

To separate sugar and extract, the alcohol must be evaporated till crystals begin to fall down, which are sugar; but they will generally be coloured by some extract, and can only be purified by repeated solutions in alcohol. Extract may be separated from sugar, by dissolving the solid, obtained by evaporation from alcohol, in a small quantity of water, and boiling it for a long while in contact with the air. The extract will gradually fall down in the form of an insoluble powder, and the sugar will remain in solution.

If tannin exist in the first solution made by cold water, its separation is easily effected by the process described page 248. The solution of isinglass must be gradually added, to prevent the existence of an excess

of animal jelly in the solution, which might be mistaken for mucilage.

When the vegetable substance, the subject of experiment, will afford no more principles to cold water, it must be exposed to hot water. This will unite to starch, if there be any, and may likewise take up more sugar, extract, and tannin, provided they be intimately combined with the other principles of the compound.

The mode of separating starch is similar to that of separating mucilage.

If, after the action of hot water, any thing remain, the action of boiling alcohol is then to be tried. This will dissolve resinous matter; the quantity of which may be known by evaporating the alcohol.

The last agent that may be applied is ether, which dissolves elastic gum, though the application is scarcely ever necessary; for if this principle be present, it may be easily detected by its peculiar qualities.

If any fixed oil, or wax, exist in the vegetable substance, it will separate during the process of boiling in water, and may be collected. Any substance not acted upon by water, alcohol, or ether, must be regarded as woody fibre.

If volatile oils exist in any vegetable substances, it is evident they may be procured, and their quantity ascertained, by distillation.

When the quantity of fixed saline, alkaline, metallic, or earthy matter in any vegetable compound, is to be ascertained, the compound must be decomposed by heat, by exposing it, if a fixed substance, in a crucible, to a long-continued red heat; and if a volatile substance, by passing it through an ignited porcelain tube. The nature of the matter so produced may be learnt by applying the tests mentioned in Lecture IV.

The only analyses in which the agricultural chemist can often wish to occupy himself, are those of substances containing principally starch, sugar, gluten, oils, mucilage, albumen, and tannin.

The two following statements will afford an idea of the manner in which the results of experiments may be arranged.

The first is a statement of the composition of ripe peas, deduced from experiments made by Einhof; the second is of the products afforded by oak bark, deduced from experiments conducted by myself:—

	Parts.
3840 parts of ripe peas afford of starch -	1265
Fibrous matter analagous to starch, with the coats of the peas -	840
A substance analagous to gluten -	559
Mucilage - - -	249
Saccharine matter - - -	81
Albumen - - -	66
Volatile matter - - -	540
Earthy phosphates - - -	11
Loss - - - -	229

1000 parts of dry oak bark, from a small tree deprived of epidermis, contain,

Of woody fibre - - - -	876
— Tannin - - - - -	57
— Extract - - - - -	31
— Mucilage - - - - -	18
— Matter rendered insoluble during evaporation, probably a mixture of albumen and extract - -	9
— Loss, partly saline matter - - -	29

To ascertain the primary elements of the different

vegetable principles, and the proportions in which they are combined, different methods of analysis have been adopted. The most simple are their decomposition by heat, or their formation into new products, by combustion.

When any vegetable principle is acted on by a strong red heat, its elements become newly arranged. Such of them as are volatile, are expelled in the gaseous form; and are either condensed as fluids, or remain permanently elastic. The fixed remainder is either carbonaceous, earthy, saline, alkaline, or metallic matter.

To make correct experiments on the decomposition of vegetable substances by heat, requires a complicated apparatus, much time and labour, and all the resources of the philosophical chemist; but such results as are useful to the agriculturist may be easily obtained. The apparatus necessary, is a green glass retort, attached by cement to a receiver, connected with a tube passing under an inverted jar of known capacity, filled with water.* A given weight of the substance is to be heated to redness, in the retort over a charcoal fire; the receiver is to be kept cool, and the process continued as long as any elastic matter is generated. The condensible fluids will collect in the receiver, and the fixed residuum will be found in the retort. The fluid products of the distillation of vegetable substances are principally water, with some acetous and mucous acids, and empyreumatic oil or tar, and in some cases ammonia. The gases are carbonic acid gas, carbonic oxide, and carburetted hydrogen; sometimes with olefiant gas, and hydrogen; and sometimes, but more rarely, with azote. Carbonic acid is the only one of those gases rapidly absorbed by water; the rest are inflammable; olefiant gas burns with a bright white light; carburetted hydrogen with a light

* See Fig. 14.

like wax; carbonic oxide with a feeble blue flame. The properties of hydrogen and azote, have been described in the last Lecture. The specific gravity of carbonic acid gas, is to that of air as 20·7, to 13·7; and it consists of one proportion of carbon 11·4, and two of oxygen 30. The specific gravity of gaseous oxide of carbon, is, taking the same standard, 13·2, and it consists of one proportion of carbon, and one of oxygen. The specific gravities of carburetted hydrogen and olefiant gas, are respectively 8 and 13; both contain four proportions of hydrogen; the first contains one proportion, the second two proportions of carbon.

If the weight of the carbonaceous residuum be added to the weight of the fluids condensed in the receiver, and they be subtracted from the whole weight of the substance, the remainder will be the weight of the gaseous matter.

The acetous and mucous acids and the ammonia formed, are usually in very small quantities; and, by comparing the proportions of water and charcoal with the quantity of the gases, taking into account their qualities, a general idea may be formed of the composition of the substance. The proportions of the elements in the greater number of the vegetable substances which can be used as food, have been already ascertained by philosophical chemists, and have been stated in the preceding pages; the analysis, by distillation, may, however, in some cases, be useful in estimating the powers of manures, in a manner that will be explained in a future Lecture.

The statements of the composition of vegetable substances, quoted from MM. Gay Lussac and Thenard, were obtained by these philosophers, by exposing the substances to the action of heated chlorate of potassa; a

body that consists of potassium, chlorine, and oxygen; and which afforded oxygen to the carbon and the hydrogen. Their experiments were made in a peculiar apparatus, and required great caution, and were of a very delicate nature. It will not, therefore, be necessary to enter upon any details of them.

It is evident, from the whole tenor of the statements which have been made, that the most essential vegetable substances consist of hydrogen, carbon, and oxygen in different proportions, generally alone, but in some few cases combined with azote. The acids, alkalies, earths, metallic oxides, and saline compounds, though necessary in the vegetable economy, must be considered as of less importance, particularly in their relation to agriculture, than the other principles; and, as it appears from M. de Saussure's table, and from other experiments, they differ in the same species of vegetable when it is raised on different soils.

MM. Gay Lussac and Thenard have deduced three propositions, which they have called *laws*, from their experiments on vegetable substances. *The first* is, "That a vegetable substance is always acid whenever the oxygen it contains is to the hydrogen in a greater proportion than in water."

The second, "That a vegetable substance is always resinous, or oily or spirituous, whenever it contains oxygen in a smaller proportion to the hydrogen, than exists in water."

The third, "That a vegetable substance is neither acid nor resinous, but is either saccharine or mucilaginous, or analogous to woody fibre or starch, whenever the oxygen and hydrogen in it are in the same proportions as in water."

New experiments upon other vegetable substances,

besides those examined by MM. Gay Lussac and Thenard, are required before these interesting conclusions can be fully admitted. Their researches establish, however, the close analogy between several vegetable compounds differing in their sensible qualities, and combined with those of other chemists, offer simple explanations of several processes in nature and art, by which different vegetable substances are converted into each other, or changed into new compounds.

Gum and sugar, excluding the different proportions of water they may contain, afford nearly the same elements by analysis; and starch differs from them only in containing a little more carbon. The peculiar properties of gum and sugar, must depend chiefly upon the different arrangement or degree of condensation of their elements; and it would be natural to conceive, from the composition of these bodies, as well as that of starch, that all three would be easily convertible one into the other; which is actually the case.

At the time of the ripening of corn, the saccharine matter in the grain, and that carried from the sap vessels into the grain, become coagulated, probably simply by losing water, and form starch. And, in the process of malting, the converse change occurs. The starch of grain is converted into sugar. As there is a little absorption of oxygen, and a formation of carbonic acid in this case, it is likely that the starch loses a little carbon, which combines with the oxygen to form carbonic acid; and probably the oxygen tends to acidify the gluten of the grain, and thus breaks down the texture of the starch; gives a new arrangement to its elements, and renders it soluble in water.

Mr. Cruikshank, by exposing syrup to a substance named phosphuret of lime, which has a great tendency

to decompose water, converted a part of the sugar into a matter analogous to mucilage. And M. Kirchhoff, recently, has converted starch into sugar by a very simple process, that of boiling in very diluted sulphuric acid. The proportions are 100 parts of starch, 400 parts of water, and 1 part of sulphuric acid by weight. This mixture is to be kept boiling for 40 hours; the loss of water by evaporation, being supplied by new quantities. The acid is to be neutralized by lime; and the sugar crystallized by cooling. This experiment has been tried with success by many persons. Sir C. Tuthill, from a pound and a half of potatoe starch, procured a pound and a quarter of crystalline, brown sugar; which he conceives possessed properties intermediate between cane-sugar and grape-sugar.

It is probable from the experiments of M. Theodore de Saussure, that the conversion of starch into sugar, in this experiment, is effected merely by its combination with water; for his experiments prove that the acid is not decomposed, and that no elastic matter is set free, and that the sugar weighs more than the starch from which it is formed: probably the colour of the sugar, is owing to the disengagement, or new combination of a little carbon, the slight excess of which, as has been just stated, constitutes the only difference (independent of the different quantities of water they may contain) perceptible by analysis between sugar and starch.

M. Bouillon la Grange, by slightly roasting starch, has rendered it soluble in cold water; and the solution evaporated afforded a substance, having the characters of mucilage. And by experiments similar to those of M. Kirchhoff, M. Braconnot has lately shown that saccharine and mucilaginous substances may be procured from various forms of woody fibre; and I

have seen specimens of soft sugar made from linen rags.

Gluten and albumen differ from the other vegetable products, principally by containing azote. When gluten is kept long in water, it undergoes fermentation; ammonia (which contains its azote) is given off with acetic acid; and a fatty matter and a substance analogous to woody fibre remain.

Extract, tannin, and gallic acid, when their solutions are long exposed to air, deposit a matter similar to woody fibre; and the solid substances are rendered analogous to woody fibre, by slight roasting; and in these cases it is probable that part of their oxygen and hydrogen is separated as water.

All the other vegetable principles differ from the vegetable acids in containing more hydrogen and carbon, or less oxygen: many of them, therefore, are easily converted into vegetable acids by a mere subtraction of some proportions of hydrogen. The vegetable acids, for the most part, are convertible into each other by easy processes. The oxalic contains most oxygen; the acetic the least; and this last substance is easily formed by the distillation of other vegetable substances, or by the action of the atmosphere on such of them as are soluble in water; probably by the mere combination of oxygen with hydrogen and carbon, or in some cases by the subtraction of a portion of hydrogen.

Alcohol, or spirits of wine, has been often mentioned in the course of these Lectures. This substance was not descriebd amongst the vegetable principles, because it has never been found ready formed in the organs of plants. It is procured by a change in the principles of saccharine matter, in a process called vinous fermentation.

The expressed juice of the grape contains sugar, mucilage, gluten, and some saline matter, principally composed of tartaric acid: when this juice, or *must*, as it is commonly called, is exposed to the temperature of about 70°, the fermentation begins; it becomes thick and turbid; its temperature increases, and carbonic acid gas is disengaged in abundance. In a few days the fermentation ceases; the solid matter that rendered the juice turbid falls to the bottom, and it clears; the sweet taste of the fluid is in great measure destroyed, and it becomes spirituous.

Fabroni has shown that the gluten in must is essential to fermentation; and that chemist has made saccharine matter ferment, by adding to its solution in water, common vegetable gluten and tartaric acid. Gay Lussac has demonstrated that must will not ferment when freed from air by boiling, and placed out of the contact of oxygen; but that fermentation begins as soon as it is exposed to the oxygen of air, a little of that principle being absorbed; and that it then continues independent of the presence of the atmosphere.

In the manufacture of ale and porter, the sugar formed during the germination of barley is made to ferment by dissolving it in water with a little yeast, which contains gluten in the state proper for producing fermentation, and exposing it to the requisite temperature; carbonic acid gas is given off as in the fermentation of must, and the liquor gradually becomes spirituous.

Similar phenomena occur in the fermentation of the sugar in the juice of apples and other ripe fruits. It appears that fermentation depends entirely upon a new arrangement of the elements of sugar; part of the carbon uniting to oxygen to form carbonic acid, and the

remaining carbon, hydrogen, and oxygen, combining as alcohol; and the use of the gluten or yeast, and the primary exposure to air, seems to be to occasion the formation of a certain quantity of carbonic acid; and this change being once produced is continued; its agency may be compared to that of a spark in producing the inflammation of gunpowder; the increase of temperature occasioned by the formation of one quantity of carbonic acid occasions the combination of the elements of another quantity.

From the experiments of M. Theodore de Saussure it appears that alcohol is composed of 100 parts of olefiant (or percarburetted hydrogen gas,) and of 63·58 water, or oxygen and hydrogen in the proportions necessary to form water.

Alcohol, in its purest known form, is a highly inflammable liquid, of specific gravity 796, at the temperature of 60°; it boils at about 170° Fahrenheit. This alcohol is obtained by repeated distillation of the strongest common spirit from the salt called by chemists muriate of lime, it having been previously heated red-hot.

The strongest alcohol obtained by the distillation of spirit without salts has seldom a less specific gravity than 825 at 60°; and it contains, according to Lowitz's experiments, 89 parts of the alcohol of 796, and 11 parts of water. The spirit established as *proof spirit* by act of parliament passed in 1762 ought to have the specific gravity of 916; and this contains nearly equal weights of pure alcohol and water.

The alcohol in fermented liquors is in combination with water, colouring matter, sugar, mucilage, and the vegetable acids. It has been often doubted whether it can be procured by any other process than distillation;

and some persons have even supposed that it *is formed* by distillation. The experiments of Mr. Brande are conclusive against both these opinions. That gentleman has shown that the colouring and acid matter in wines may be, for the most part, separated in a solid form by the action of a solution of sugar of lead (acetate of lead), and that the alcohol may then be obtained by abstracting the water by means of hydrate of potassa or muriate of lime, without artificial heat.

The intoxicating powers of fermented liquors depend on the alcohol that they contain; but their action on the stomach is modified by the acid, saccharine, or mucilaginous substances they hold in solution. Alcohol probably acts with most efficacy when it is most loosely combined; and its energy seems to be impaired by union with large quantities of water, or with sugar or acid, or extractive matter.

The table in the following page contains the results of Mr. Brande's experiments on the quantity of alcohol of 825 at 60°, in different fermented liquors.

The spirits distilled from different fermented liquors differ in their flavour: for peculiar odorous matter, or volatile oils, rise in most cases with the alcohol. The spirit from malt usually has an empyreumatic taste like that of the oil, formed by the distillation of vegetable substances. The best brandies seem to owe their flavour to a peculiar oily matter, formed probably by the action of the tartaric acid on alcohol; and rum derives its characteristic taste from a principle in the sugar cane.

Wine.	Proportion of Alcohol per cent. by measure.	Wine.	Proportion of Alcohol per cent. by measure.
Port - -	19·00	Frontignac - -	12·79
Ditto - -	21·40	Coti Roti - -	12·32
Ditto - -	22·30	Roussillon - -	17·26
Ditto - -	23·39	Ditto - -	19·00
Ditto - -	23·71	Cape Madeira -	18·11
Ditto - -	24·29	Ditto - -	20·50
Ditto - -	25·83	Ditto - -	22·94
Average - -	22·96	Cape Muscat -	18·25
Madeira - -	19·24	White Constantia -	19·75
Ditto (Sercial) -	21·40	Red Constantia -	18·92
Ditto - -	23·93	Tent - -	13·30
Ditto - -	24·42	Sheraaz - -	15·52
Average - -	22·27	Syracuse - -	15·28
Sherry - -	18·25	Nice - -	14·63
Ditto - -	18·79	Tokay - -	9·88
Ditto - -	19·81	Lissa - -	26·47
Ditto - -	19·83	Ditto - -	24·35
Average - -	19·17	Teneriffe - -	19·79
Claret - -	12·91	Colares - -	19·75
Ditto - -	14·08	Lachryma Christi -	19·70
Ditto - -	16·32	Vidonia - -	19·25
Ditto - -	17·11	Alba flora - -	17·26
Average - -	15·10	Zante - -	17·05
Calcavella - -	18·10	Lunel - -	15·52
Ditto - -	19·20	Sauterne - -	14·22
Lisbon - -	18·94	Barsac - -	13·86
Malaga - -	17·26	Raisin Wine -	25·77
Ditto - -	18·94	Ditto - -	26·40
Bucellas - -	18·49	Ditto - -	23·20
Red Madeira -	18·40	Orange Wine -	11·26
Ditto - -	22·30	Grape Wine -	18·11
Malmsey Madeira -	16·40	Currant Wine -	20·55
Marsala - -	25·05	Gooseberry Wine -	11·84
Ditto - -	26·03	Elder Wine - -	8·79
Red Champagne -	11·30	Mead - -	7·32
Ditto - -	12·56	Cyder - -	9·87
White Champagne -	12·80	Ditto - -	5·21
Still Champagne -	13·80	Perry - -	7·26
Burgundy - -	14·53	Brown Stout -	6·80
Ditto - -	11·95	Ale (Burton) -	8·88
Ditto - -	15·22	Edinburgh -	6·20
Ditto - -	16·80	Dorchester -	5·56
White Hermitage -	17·43	London Porter -	4·20
Red Hermitage -	12·32	Small Beer -	1·28
Hock - -	14·37	Brandy - -	53·39
Ditto - -	13·00	Rum - -	53·68
Ditto - -	8·88	Hollands - -	51·60
Vin de Grave -	12·80	Scotch Whisky -	54·32
Ditto - -	13·94	Irish Whisky -	53·90

All the common spirits may, I find, be deprived of their peculiar flavour by repeatedly digesting them with a mixture of well-burnt charcoal and quicklime; they then afford pure alcohol by distillation. The cognac brandies, I find, contain vegetable prussic acid, and their flavour may be imitated by adding to a solution of alcohol in water of the same strength, a few drops of the ethereal oil of wine produced during the formation of ether,* and a similar quantity of vegetable prussic acid procured from laurel leaves or any bitter kernels.

I have mentioned *ether* in the course of this Lecture; this substance is procured from alcohol by distilling a mixture of equal parts of alcohol and sulphuric acid. It is the lightest known liquid substance, being of specific gravity 632 at 60°. It is very volatile and rises in vapour, even by the heat of the body. It is highly inflammable. In the formation of ether it is most probable, from the experiments of M. de Saussure, that the elements of water merely are separated from the alcohol by the sulphuric acid, and that ether differs from alcohol in containing a larger proportion of carbon and hydrogen. Like alcohol, it possesses intoxicating powers.

A number of the changes taking place in the vegetable principles depend upon the separation of oxygen and hydrogen as water from the compound; but there is one of very great importance, in which a new combination of the elements of water is the principal operation. This is in the manufacture of bread. When any kind of flour, which consists principally of starch, is

* In the process of the distillation of alcohol and sulphuric acid after the ether is procured; by a higher degree of heat, a yellow fluid is produced; which is the substance in question. It has a fragrant smell and an agreeable taste.

made into a paste with water, and immediately and gradually heated to about 440°, it increases in weight, and is found entirely altered in its properties; it has lost its solubility in water, and its power of being converted into sugar. In this state it is unleavened bread.

When the flour of corn or the starch of potatoes, mixed with boiled potatoes, is made into a paste with water, kept warm, and suffered to remain 30 or 40 hours, it ferments, carbonic acid gas is disengaged from it, and it becomes filled with globules of elastic fluid. In this state it is raised dough, and affords, by baking, leavened bread; but this bread is sour and disagreeable to the taste; and leavened bread for use is made by mixing a little dough, that has fermented, with new dough, and kneading them together, or by kneading the bread with a small quantity of yeast.

In the formation of wheaten bread more than $\frac{1}{4}$ of the elements of water combine with the flour; more water is consolidated in the formation of bread from barley, and still more in that from oats; but the gluten in wheat, being in much larger quantity than in other grain, seems to form a combination with the starch and water, which renders wheaten bread more digestible than the other species of bread.

The arrangement of many of the vegetable principles in the different parts of plants has been incidentally mentioned in this Lecture; but a more particular statement is required to afford just views of the relation between their organization and chemical constitution, which is an object of great importance. The tubes and hexagonal cells in the vascular system of plants are composed of woody fibre; and when they are not filled with fluid matter they contain some of the solid mate-

rials which formed a constituent part of the fluids belonging to them.

In the roots, trunk, and branches, the bark, alburnum, and heart-wood, the leaves and flowers, the great basis of the solid parts is woody fibre. It forms by far the greatest part of the heart-wood and bark; there is less in the alburnum, and still less in the leaves and flowers. The alburnum of the birch contains so much sugar and mucilage, that it is sometimes used in the north of Europe as a substitute for bread. The leaves of the cabbage, broccoli, and sea-cale contain much mucilage, a little saccharine matter, and a little albumen. From 1000 parts of the leaves of common cabbage I obtained 41 parts of mucilage, 24 of sugar, and 8 of albuminous matter.

In bulbous roots, and sometimes in common roots, a large quantity of starch, albumen, and mucilage are often found deposited in the vessels; and they are most abundant after the sap has ceased to flow; and afford a nourishment for the early shoots made in spring. The potatoe is the bulb that contains the largest quantity of soluble matter in its cells and vessels; and it is of most importance in its application as food. Potatoes in general afford from $\frac{1}{5}$ to $\frac{1}{4}$ their weight of dry starch. From 100 parts of the common *Kidney potatoe*, Dr. Pearson obtained from 32 to 28 parts of meal, which contained from 23 to 20 of starch and mucilage: and 100 parts of the *Apple potatoe*, in various experiments, afforded me from 18 to 20 parts of pure starch. From 5 pounds of the variety of the potatoe called *Captain hart*, Mr. Skrimshire, jun. obtained 12 oz. of starch; from the same quantity of the *Rough red* potatoe, $10\frac{1}{2}$ oz.; from the *Moulton white*, $11\frac{3}{4}$; from the *Yorkshire kidney*, $10\frac{3}{4}$ oz.; from *Hundred eyes*, 9 oz.; from *Purple*

red, 8½; from *Ox noble*, 8¼. The other soluble substances in the potatoe are albumen and mucilage.

From the analysis of Einhoff it appears that 7680 parts of potatoe afford,

Of Starch - - - - -	1153
— Fibrous matter analogous to starch -	540
— Albumen - - - - -	107
— Mucilage in the state of a saturated solution - - - -	312
	2122

So that a fourth part of the weight of the potatoe at least may be considered as nutritive matter. Mr. Knight informs me, that he has found the best potatoes, such as the Irish apple, to possess much greater specific gravity, varying from 1075 to 1100; and it is probable that their nutritive properties are nearly proportionate to their specific gravities.

The turnip, carrot, and parsnep, afford principally saccharine, mucilaginous, and extractive matter. I obtained from 1000 parts of common turnips, 7 parts of mucilage, 34 of saccharine matter, and nearly 1 part of albumen; 1000 parts of carrots furnished 95 parts of sugar, 3 parts of mucilage, and ½ part of extract; 1000 parts of parsnep afforded 90 parts of saccharine matter, and 9 parts of mucilage; the *Walcheren* or *white carrot* gave, in 1000 parts, 98 parts of sugar, 2 parts of mucilage, and 1 of extract.

Fruits, in the organization of their soft parts, approach to the nature of bulbs. They contain a certain quantity of nourishment laid up in their cells for the use of the embryon plant; mucilage, sugar, starch, are found in many of them often combined with vegetable acids. Most of the fruit trees common in Britain have

been naturalized on account of the saccharine matter they contain, which, united to the vegetable acids and mucilage, renders them at once agreeable to the taste, and nutritive.

The value of fruits for the manufacture of fermented liquors may be judged of from the specific gravity of their expressed juices; but the quantity of juice and the consistence of the pulp differ widely in different species of fruits, and therefore the specific gravity of the fruit will not always indicate the value of its fermented produce. The best cyder and perry are made from those apples and pears that afford the densest juices; and a comparison between different fruits may be made with tolerable accuracy by plunging them together into a saturated solution of salt, or a strong solution of sugar; those that sink deepest will afford the richest juice.

Starch, or coagulated mucilage, forms the greatest part of the seeds and grains used for food; and they are generally combined with gluten, oil, or albuminous matter. In corn, with gluten; in peas and beans, with albuminous matter; and in rape-seed, hemp seed, linseed, and the kernels of most nuts, with oils.

I found 100 parts of good full-grained wheat sown in autumn to afford

Of Starch	-	77
— Gluten	-	19

100 parts of wheat sown in spring,

Of Starch	-	70
— Gluten	-	24

100 parts of Barbary wheat,

Of Starch	-	74
— Gluten	-	23

100 parts of Sicilian wheat,

Of Starch	-	75
— Gluten	-	21

I have examined different specimens of North American wheat; all of them have contained rather more gluten than the British. In general, the wheat of warm climates abounds more in gluten, and in insoluble parts; and it is of greater specific gravity, harder, and more difficult to grind.

The wheat of the south of Europe, in consequence of the larger quantity of gluten it contains, is peculiarly fitted for making macaroni, and other preparations of flour, in which a glutinous quality is considered as an excellence.

In some experiments made on barley, I obtained from 100 parts of full and fair Norfolk barley,

Of Starch	- - -	79
— Gluten	- - -	6
— Husk	- - -	8

The remaining 7 parts saccharine matter. The sugar in barley is probably the chief cause why it is more proper for malting than any other species of grain.

Einhoff has published a minute analysis of barley meal. He found in 3840 parts,

Of volatile matter	- -	360
— Albumen	- - -	44
— Saccharine matter	- -	200
— Mucilage	- - -	176
— Phosphate of lime, with some albumen		9
— Gluten	- - -	135
— Husk, with some gluten and starch	-	260
— Starch not quite free from gluten	-	2580
— Loss	- - -	78

Rye afforded to Einhoff, in 3840 parts, 2520 meal, 930 husk, and 390 moisture; and the same quantity of meal analyzed gave,

Of Starch - - -	2345
— Albumen - - -	116
— Mucilage - - -	426
— Saccharine - - -	126
— Gluten not dried - -	364

Remainder husk and loss.

I obtained from 1000 parts of rye, grown in Suffolk, 61 parts of starch and 5 parts of gluten.

100 parts of oats, from Sussex, afforded me 59 parts of starch, 6 of gluten, and 2 of saccharine matter.

1000 parts of peas, grown in Norfolk, afforded me 501 parts of starch, 22 parts of saccharine matter, 35 parts of albuminous matter, and 16 parts of extract, which became insoluble during evaporation of the saccharine fluid.

From 3840 parts of marsh beans (*Vicia faba*), Einhoff obtained,

Of Starch - - -	1312
— Albumen - - -	31
— other matters which may be conceived nutritive; such as gummy, starchy, fibrous matter analogous to animal matter - -	1204

The same quantity of kidney beans (*Phaseolus vulgaris*), afforded,

Of matter analogous to starch -	1805
— Albumen and matter approaching to animal matter in its nature -	851
— Mucilage - - - -	799

From 3840 parts of lentiles, he obtained 1260 parts

of starch, and 1433 of a mattter analogous to animal matter.

The matter analagous to animal matter is described by Einhoff, as a glutinous substance insoluble in water; soluble in alcohol; when dry, having the appearance of glue; probably a peculiar modification of gluten.

From 16 parts of hemp seed, Bucholz obtained 3 parts of oil, 3½ parts of albumen, about 1⅝ of saccharine and gummy matter. The insoluble husks and coats of the seeds weighed 6⅛ parts.

The different parts of flowers contain different substances: the pollen, or impregnating dust of the date, has been found by Fourcroy and Vauquelin to contain a matter analagous to gluten, and a soluble extract abounding in malic acid. Link found in the pollen of the hazel-tree, much tannin and gluten.

Saccharine matter is found in the nectarium of flowers, or the receptacles within the corolla, and by tempting the larger insects into the flowers, it renders the work of impregnation more secure; for the pollen is often by their means applied to the stigma; and this is particularly the case when the male and female organs are in different flowers or different plants.

It has been stated, that the fragrance of flowers depends upon the volatile oils they contain; and these oils, by their constant evaporation, surround the flower with a kind of odorous atmosphere; which, at the same time that it entices larger insects, may probably preserve the parts of fructification from the ravages of smaller ones. Volatile oils, or odorous substances, seem particularly destructive to these minute insects and animalcules which feed on the substance of vegetables: thousands of aphides may be usually seen in the stalk and leaves of the rose; but none of them are ever observed on the

flower. Camphor is used to preserve the collections of naturalists. The woods that contain aromatic oils are remarked for their indestructibility, and for their exemption from the attacks of insects: this is particularly the case with the cedar, rose-wood, and cypress. The gates of Constantinople, which were made of this last wood, stood entire from the time of Constantine, their founder, to that of Pope Eugene IV., a period of 1100 years.

The petals of many flowers afford saccharine and mucilaginous matter. The white lily yields mucilage abundantly; and the orange lily a mixture of mucilage and sugar; the petals of the convolvulus afford sugar, mucilage, and albuminous matter.

The chemical nature of the colouring matters of flowers has not as yet been subject to any very accurate observation. These colouring matters, in general, are very transient, particularly the blues and reds; alkalies change the colours of most flowers to green, and acids to red. An imitation of the colouring matter may be made by digesting solutions of gall-nuts with chalk: a green fluid is obtained, which becomes red by the action of an acid; and has its green colour restored by means of alkalies.

The yellow colouring matters of flowers are the most permanent; the carthamus contains a red and a yellow colouring matter: the yellow colouring matter is easily dissolved by water; and from the red, rouge is prepared by a process which is kept secret.

The same substances as exist in the solid parts of plants are found in their fluids, with the exception of woody fibre. Fixed and volatile oils, containing resin or camphor, or analogous substances in solution, exist in the cylindrical tubes belonging to a number of plants.

Different species of Euphorbia emit a milky juice, which when exposed to air deposits a substance analogous to starch, and another similar to gluten.

Opium, gum elastic, gamboge, the poisons of the *Upas Antiar* and *Tieute,* and other substances that exude from plants, may be considered as peculiar juices belonging to appropriate vessels.

The sap of plants, in general, is very compound in its nature; and contains more saccharine, mucilaginous, and albuminous matter in the alburnum; and most tannin and extract in the bark. The cambium, which is the mucilaginous fluid found in trees between the wood and the bark, and which is essential to the formation of new parts, seems to be derived from these two kinds of sap; and probably is a combination of the mucilaginous and albuminous matter of one, with the astringent matter of the other, in a state fitted to become organized by the separation of its watery parts.

The alburnous saps of some trees have been chemically examined by Vauquelin. He found in those of the elm, beech, yoke elm, hornbeam, and birch, extractive and mucilaginous matter, and acetic acid combined with potassa or lime. The solid matter afforded by their evaporation yielded an ammoniacal smell, probably owing to albumen: the sap of the birch afforded saccharine matter.

Deyeux in the sap of the vine and the yoke elm has detected a matter analogous to the curd of milk. I found a substance similar to albumen in the sap of the walnut tree.

I found the juice which exudes from the vessels of the marsh-mallow when cut, to be a solution of mucilage.

The fluids contained in the sap vessels of wheat and

barley, afforded in some experiments which I made on them, mucilage, sugar, and a matter which coagulated by heat; which last was most abundant in wheat.

The following table contains a statement of the quantity of soluble or nutritive matters existing in varieties of the different substances that have been mentioned, and of some others which are used as articles of food, either for man or cattle. The analyses are my own; and were conducted with a view to a knowledge of the general nature and quantity of the products, and not of their intimate chemical composition. The soluble matters afforded by the grasses, except that from the fiorin in winter, were obtained by Mr. Sinclair, gardener to the Duke of Bedford, from given weights of the grasses cut when the seeds were ripe: they were sent to me by his Grace's desire for chemical examination, and form part of the results of an important and extensive series of experiments on grasses made by the direction of the Duke, at Woburn Abbey, when pursuing those plans for the improvement of agriculture, the origin of which has thrown so much glory on the memory of his illustrious brother.

All these substances were submitted to experiment green, and in their natural states. It is probable that the excellence of the different articles, as food, will be found to be in a great measure proportional to the quantities of soluble or nutritive matters they afford; but still these quantities cannot be regarded as *absolutely* denoting their value. Albuminous or glutinous matters have the characters of animal substances; sugar is more nourishing, and extractive matter less nourishing, than any other principles composed of carbon, hydrogen, and oxygen. Certain combinations likewise of these substances may be more nutritive than others.

Table of the Quantities of Soluble or Nutritive Matters afforded by 100 Parts of different Vegetable Substances.

Vegetables or Vegetable Substance.	Whole Quantity of Soluble or Nutritive Matter.	Mucilage or Starch.	Saccharine Matter or Sugar.	Gluten or Albumen	Extract or Matter rendered insoluble during Evaporation.
Middlesex wheat, average crop	955	765	—	190	
Spring wheat	940	700	—	240	
Mildewed wheat of 1806	210	178	—	32	
Blighted wheat of 1804	650	520	—	130	
Thick-skinned Sicilian wheat of 1810	955	725	—	230	
Thin-skinned Sicilian wheat of 1810	961	722	—	239	
Wheat from Poland	950	750	—	200	
North American wheat	955	730	—	225	
Norfolk barley	920	790	70	60	
Oats from Scotland	743	641	15	87	
Rye from Yorkshire	792	645	38	109	
Common bean	570	426	—	103	41
Dry peas	574	501	22	35	16
Potatoes	from 260 to 200	from 200 to 155	from 20 to 15	from 40 to 30	
Linseed cake	151	123	11	17	
Red beet	148	14	121	13	
White beet	136	13	119	4	
Parsnep	98	9	90		
Carrots	99	3	95		
Common turnips	42	7	34	1	
Swedish turnips	64	9	51	2	2
Cabbage	73	41	24	8	
Broad-leaved clover	39	31	3	2	3
Long-rooted clover	39	30	4	3	2
White clover	32	29	1	3	5
Sainfoin	39	28	2	3	6
Lucerne	23	18	1	—	4
Meadow fox-tail grass	33	24	3	—	6
Perennial rye grass	39	26	4	—	5
Fertile meadow grass	78	65	6	—	7
Roughish meadow grass	39	29	5	—	6
Crested dog's-tail grass	35	28	3	—	4
Spiked fescue grass	19	15	2	—	2
Sweet-scented soft grass	82	72	4	—	6
Sweet-scented vernal grass	50	43	4	—	3
Fiorin	54	46	5	1	2
Fiorin cut in winter	76	64	8	1	3

I have been informed by Sir Joseph Banks, that the Derbyshire miners, in winter, prefer oat-cakes to wheaten bread; finding that this kind of nourishment enables them to support their strength and perform their labour better. In summer, they say oat-cake heats them, and they then consume the finest wheaten bread they can procure. Even the skin of the kernel of oats probably has a nourishing power, and is rendered partly soluble in the stomach with the starch and gluten. In most countries of Europe, except Britain, and in Arabia, horses are fed with corn of different kinds, mixed with chopped straw; and the chopped straw seems to act the same part as the husk of the oat. In the mill 14 lbs. of good wheat yield on an average 13 lbs. of flour; the same quantity of barley 12 lbs., and of oats only 8 lbs.

In the South of Europe, hard or thin-skinned wheat is in higher estimation, than soft or thick-skinned wheat; the reason of which is obvious, from the larger quantity of gluten and nutritive matter it contains. I have made an analysis of only one specimen of thin-skinned wheat, so that other specimens may possibly contain more nutritive matter than that in the table; the Barbary and Sicilian wheats, before referred to, were thick-skinned wheats. In England, the difficulty of grinding thin-skinned wheat is an objection; but this difficulty is easily overcome by moistening the corn.*

* For the following note on this subject I am indebted to the kindness of the Right Hon. Sir Joseph Banks, Bart., K.B.:—

Information received from John Jeffrey, Esq., his Majesty's Consul-General at Lisbon, in Answer to Queries transmitted to him, from the Comm. of P.C. for Trade, dated Jan. 12, 1812.

"To grind hard corn with the mill-stones used in England, the wheat must be well screened, then sprinkled with water at the miller's discretion, and laid in heaps and frequently turned and thoroughly mixed,

which will soften the husk, so as to make it separate from the flour in grinding, and of course give the flour a brighter colour; otherwise the flinty quality of the wheat, and the thinness of the skin will prevent its separation, and will render the flour unfit for making into bread.

"I am informed by a miller of considerable experience, and who works his mills entirely with the stones from England or Ireland, that he frequently prepares the hard Barbary corn by immersing it in water in close wicker baskets, and spreading it thinly on a floor to dry; much depends on the judgment and skill of the miller in preparing the corn for the mill according to its relative quality. I beg to observe, that it is not from this previous process of wetting the corn that the weight in the flour of hard corn is increased; but from its natural quality it imbibes considerably more water in making it into bread. The mill-stones must not be cut too deep, but the furrows very fine, and picked in the usual way. The mills should work with less velocity in grinding hard corn than with soft, and set to work at first with soft corn, till the mill ceases to work well; then put on the hard corn. Hard wheat always sells at a higher price in the market than soft wheat, on an average of ten to fifteen per cent.; as it produces more flour in proportion, and less bran than the soft corn.

"Flour made from hard wheat is more esteemed than what is made from soft corn; and both sorts are applied to every purpose.

"The flour of hard wheat is in general superior to that made from soft; and there is no difference in the process of making them into bread; but the flour from hard wheat will imbibe and retain more water in making into bread, and will consequently produce more weight of bread: it is the practice here, and which I am persuaded it would be advisable to adopt in England, to make bread with flour of hard and soft wheat, which by being mixed, will make the bread much better.

(Signed) "JOHN JEFFREY."

LECTURE IV.

On Soils: their Constituent Parts.—On the Analysis of soils.—Of the Uses of the Soil.—Of the Rocks and Strata found beneath the Soils.—Of the Improvement of Soil.

No subjects are of more importance to the farmer than the nature and improvement of soils; and no parts of the doctrines of agriculture are more capable of being illustrated by chemical inquiries.

Soils are extremely diversified in appearance and quality; yet, as it was stated in the Introductory Lecture, they consist of different proportions of the same elements; which are in various states of chemical combination, or mechanical mixture.

The substances which constitute soils have been already mentioned. They are certain compounds of the earths, silica, lime, alumina, magnesia, and of the oxides of iron and manganesum; animal and vegetable matters in a decomposing state, and saline, acid, or alkaline combinations.

In all chemical experiments on the composition of soils connected with agriculture, the constituent parts obtained are compounds: and they act as compounds in nature: it is in this state, therefore, that I shall describe their characteristic properties.

1. *Silica*, or the earth of *flints*, in its pure and crystallized form, is the substance known by the name of rock crystal, or Cornish diamond. As it is procured by

chemists, it appears in the form of a white impalpable powder. It is not soluble in the common acids, but dissolves by heat in fixed alkaline lixivia. It is an incombustible substance, for it is saturated with oxygen. I have proved it to be a compound of oxygen and the peculiar combustible body which I have named silicum; and from the experiments of Berzelius, it is probable that it contains nearly equal weights of these two elements.

2. The sensible properties of *lime* are well known. It exists in soils usually united to carbonic acid, which is easily disengaged from it by the attraction of the common acids. It is sometimes found combined with the phosphoric and sulphuric acids. Its chemical properties and agencies in its pure state will be described in the lecture on manures obtained from the mineral kingdom. It is soluble in nitric and muriatic acids, and forms a substance with sulphuric acid difficult of solution, called gypsum. It is not soluble in alkaline solutions. It consists of one proportion 40 of the peculiar metallic substance, which I have named calcium; and one proportion 15 of oxygen.

3. *Alumina* exists in a pure and crystallized state in the white sapphire, and united to a little oxide of iron and silica in the other oriental gems. In the state in which it is procured by chemists, it appears as a white powder, soluble in acids and fixed alkaline liquors. From my experiments, it appears that alumina consists of one proportion 33 of aluminum, and one 15 of oxygen.

4. *Magnesia* exists in a pure crystallized state, constituting a mineral like talc found in North America. In its common form it is the *magnesia usta*, or calcined magnesia of druggists. It generally exists in soils

combined with carbonic acid. It is soluble in all the mineral acids; but not in alkaline lixivia. It is distinguished from the other earths found in soils by its ready solubility in solutions of alkaline carbonates, saturated with carbonic acid. It appears to consist of 38 magnesium and 15 oxygen.

5. There are two well-known *oxides of iron*, the black and the brown. The black is the substance that flies off when red-hot iron is hammered. The brown oxide may be formed by keeping the black oxide red-hot for a long time in contact with air. The first seems to consist of one proportion of iron 103, and two of oxygen 30; and the second of one proportion of iron 103, and three proportions of oxygen 45. The oxides of iron sometimes exist in soils combined with carbonic acid. They are easily distinguished from other substances by their giving, when dissolved in acids, a black colour to solution of galls, and a bright blue precipitate to solution of prussiate of potassa and iron.

6. *The oxide of manganesum* is the substance commonly called manganese, and used in bleaching. It appears to be composed of one proportion of manganesum 113, and three of oxygen 45. It is distinguished from the other substances found in soils, by its property of decomposing muriatic acid, and converting it into chlorine.

7. *Vegetable and animal matters* are known by their sensible qualities, and by their property of being decomposed by heat. Their characters may be learnt from the details in the last lecture.

9. The *saline compounds* found in soils, are common salt, sulphate of magnesia, sometimes sulphate of iron, nitrates of lime and of magnesia, sulphate of potassa, and carbonates of potassa and soda. To describe their

characters minutely will be unnecessary: the tests for most of them have been noticed, p. 269.

The silica in soils is usually combined with alumina and oxide of iron, or with alumina, lime, magnesia, and oxide of iron, forming gravel and sand of different degrees of fineness. The carbonate of lime is usually in an impalpable form; but sometimes in the state of calcareous sand. The magnesia, if not combined in the gravel and sand of soil, is in a fine powder united to carbonic acid. The impalpable part of the soil, which is usually called clay or loam, consists of silica, alumina, lime, and magnesia; and is, in fact, usually of the same composition as the hard sand, but more finely divided. The vegetable or animal matters (and the first is by far the most common in soils,) exist in different states of decomposition. They are sometimes fibrous, sometimes entirely broken down and mixed with the soil.

To form a just idea of soils, it is necessary to conceive different rocks decomposed, or ground into parts and powder of different degrees of fineness, some of their soluble parts dissolved by water, and that water adhering to the mass, and the whole mixed with larger or smaller quantities of the remains of vegetables and animals in different stages of decay.

It will be necessary to describe the processes by which all the varieties of soils may be analysed. I shall be minute in these particulars, and, I fear, tedious: but the philosophical farmer will, I trust, feel the propriety of full details on this subject.

The instruments required for the analysis of soils are few, and but little expensive. They are, a balance capable of containing a quarter of a pound of common soil, and capable of turning when loaded with a grain; a

set of weights from a quarter of a pound troy to a grain; a wire sieve, sufficiently coarse to admit a mustard seed through its apertures; an Argand lamp and stand; some glass bottles; Hessian crucibles; porcelain, or queen's ware evaporating basins; a Wedgewood pestle and mortar; some filters made of half a sheet of blotting paper, folded so as to contain a pint of liquid, and greased at the edges; a bone knife, and an apparatus for collecting and measuring aëriform fluids.

The chemical substances or reagents required for separating the constituent parts of the soil, have, for the most part, been mentioned before; they are muriatic acid (*spirit of salt*), sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash and iron, succinate of ammonia, soap lye, or solution of potassa, solutions of carbonate of ammonia, of muriate of ammonia, of neutral carbonate of potash, and nitrate of ammonia.

In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and in this case one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils, when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground-glass stoppers.

The quantity of soil most convenient for a perfect analysis, is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus, if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2; that is, it will be twice as heavy as water; and if it gained 165 grains, its specific gravity would be 1825, water being 1000.

It is of importance that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus, siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; ferruginous soils are of a red or yellow colour; and calcareous soils are soft.

1. Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter,

and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a basin of porcelain, to a temperature equal to 300 Fahrenheit; and if a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish; as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will, perhaps, remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted, and when in 400 grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain much vegetable or animal matter, or a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and siliceous earth probably forms the greatest part of it.

2. None of the loose stones, gravel, or large vegetable fibres, should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and, in consequence, influence the fertility of the land. The

next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily cut with a knife, and incapable of effervescing with acids.

3. The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marle, vegetable and animal matter, and the matter soluble in water. This may be effected in a way sufficiently accurate, by boiling the soil in three or four times its weight of water; and when the texture of the soil is broken down, and the water cool, by agitating the parts together, and then suffering them to rest. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the highly divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and the respective quantities noted down. The water of lixiviation must

be preserved, as it will be found to contain the saline and soluble animal or vegetable matters, if any exist in the soil.

4. By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely-divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part; it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole indicates the proportion of calcareous sand.

5. The finely-divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy is the most difficult part of the subject.

The first process to be performed in this part of the analysis is the exposure of the fine matter of the soil to the action of muriatic acid. This substance should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy matter; but diluted with double its volume of water. The mixture should be often stirred, and suffered to

remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron; but very seldom any alumina.

The fluid should be passed through a filter; the solid matter collected, washed with rain-water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of prussiate of potassa and iron must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in till no farther effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red; the result is oxide of iron, which may be mixed with a little oxide of manganesum.

Into the fluid freed from oxide of iron, a solution of neutralized carbonate of potash must be poured, till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

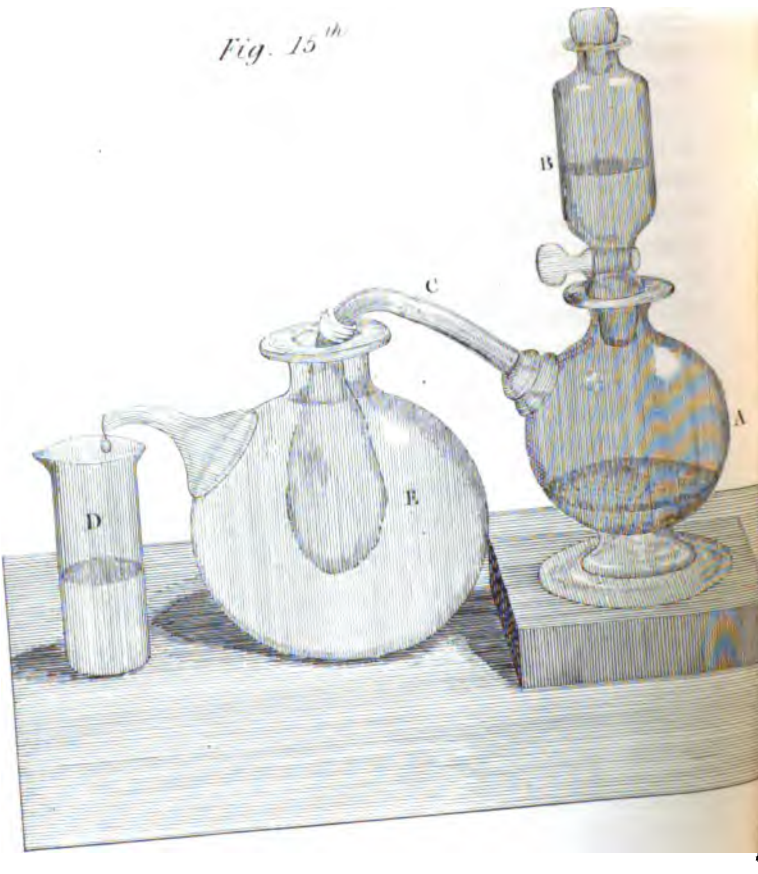
The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumina should, from

PLATE 8.

Fig. 15th



peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling it for a few minutes with soap-lye, sufficient to cover the solid matter: this substance dissolves alumina, without acting upon carbonate of lime.

Should the finely-divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* nearly 43 per cent., so that when the quantity of this elastic fluid given out by any soil during the solution of its calcareous matter in an acid is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process, by diminution of weight, is employed, two parts of the acid, and one part of the mattor of the soil, must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases: the difference between their weight before and after the experiment denotes the quantity of carbonic acid lost; for every four grains and a quarter of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by a peculiar pneumatic apparatus,*

† Fig. 15. A, B, C, D, represent the different parts of this apparatus. A represents the bottle for receiving the soil. B the bottle containing the acid, furnished with a stop-cock. C the tube connected with a flaccid bladder. D the graduated measure. E the bottle for containing the bladder. When this instrument is used, a given quantity of

in which its bulk may be measured by the quantity of water it displaces.

6. After the calcareous parts of the soil have been acted upon by muriatic acid, the next process is to ascertain the quantity of finely-divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by strongly igniting it in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic rod, so as to expose new surfaces continually to the air: the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible, without very refined and difficult experiments, to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted, during the incineration, is similar to that of burnt feathers, it is a certain indication of some substance either animal, or analagous to animal matter; and a copious blue flame, at the time of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when it is necessary that the experiment should be very quickly performed,

soil is introduced into A. B is filled with muriatic acid diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of A, which is ground to receive it. The tube D is introduced into the lower orifice of A, and the bladder connected with it placed in its flaccid state into E, which is filled with water. The graduated measure is placed under the tube of E. When the stop-cock of B is turned, the acid flows into A, and acts upon the soil; the elastic fluid generally passes through C into the bladder, and displaces a quantity of water in E equal to it in bulk, and this water flows through the tube into the graduated measure; and gives by its volume the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which two grains of carbonate of lime may be estimated.

the destruction of the decomposable substances may be assisted by the agency of nitrate of ammonia, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It accelerates the dissipation of the animal and vegetable matter, which it causes to be converted into elastic fluids; and it is itself, at the same time, decomposed and lost.

7. The substances remaining after the destruction of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumina and silica, with combined oxide of iron, or of manganesum.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every 100 grains 2 drachms, or 120 grains of acid.

The substance remaining after the action of the acid may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumina and the oxide of iron and manganesum, if any exist, are all dissolved by the sulphuric acid: they may be separated by succinate of ammonia, added to excess, which throws down the oxide of iron; and by soap lye, which will dissolve the alumina, but not the oxide of manganesum; the weights of the oxides, ascertained after they have been heated to redness, will denote their quantities.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid; this, however, is rarely the case; but the pro-

cess for detecting them, and ascertaining their quantities, is the same in both instances.

The method of analysis, by sulphuric acid, is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potassa must be employed as the agent, and the residuum of the incineration (6) must be heated red for half an hour, with four times its weight of this substance, in a crucible of silver, or of well-baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron, and all the earths, except silica, will be dissolved in combination as muriates. The silica, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

8. If any saline matter, or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in a proper dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be like that of burnt feathers, it contains animal or albuminous matter; if it be white, crystalline, and not destructible by heat, it may be considered as principally saline matter; the nature of which may be known by the tests described, p. 269.

9. Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a par-

ticular process upon it. A given weight of it, for instance 400 grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filtre, and exposed for some days to the atmosphere in an open vessel. If any notable quantity of sulphate of lime (*gypsum*) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched. It would not fall within the limits assigned to this lecture to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Other earths and metallic oxides are now and then found in them, but in quantities too minute to bear any relation to fertility or barrenness, and the search for them would make the analysis much more complicated, without rendering it more useful.

10. When the examination of a soil is completed, the products should be numerically arranged, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process just described (9), a correction must be made for the general process, by subtract-

P 2

ing a sum equal to their weight from the quantity of carbonate of lime obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they were procured.

Thus, I obtained from 400 grains of a good siliceous sandy soil from a hop-garden near Tunbridge, Kent, —

		Grains.
Of water of absorption - - -		19
Of loose stones and gravel, principally siliceous - - - -		53
Of undecompounded vegetable fibres -		14
Of fine siliceous sand - - -		212
Of minutely divided matter separated by agitation and filtration, and consisting of —		
Carbonate of lime - - -	19	
Carbonate of magnesia - -	3	
Matter destructible by heat, principally vegetable - -	15	
Silica - - - -	21	
Alumina - - - -	13	
Oxide of iron - - -	5	
Soluble matter, principally common salt and vegetable extract -	3	
Gypsum - - - -	2	
	—	81
Amount of all the products		379
Loss - - -		21

The loss in this analysis is not more than usually occurs, and it depends upon the impossibility of collecting the whole quantities of the different precipitates, and upon the presence of more moisture than is accounted for in the water of absorption, and which is lost in the different processes.

When the experimenter is become acquainted with the use of the different instruments, the properties of the reagents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid (7) may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air (8); in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid (9); and when a soil is extremely dense and heavy, and after being heated to redness, strongly attracted by the magnet, he must particularly attend to the quantity of iron it contains; and, in this case, the muriatic acid will be the principal agent.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but, perhaps, there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn the properties of

the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

Plants, being possessed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both as affording them nourishment and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface, and their leaves exposed to the free atmosphere. As the systems of roots, branches, and leaves are very different in different vegetables, so they flourish most in different soils; the plants that have bulbous roots require a looser and lighter soil than such as have fibrous roots; and the plants possessing only short fibrous radicles demand a firmer soil than such as have tap roots, or extensive lateral roots.

A good turnip soil from Holkham, Norfolk, afforded me 8 parts out of 9 siliceous sand; and the finely divided matter consisted of

Carbonate of lime - - -	63
Silica - - - -	15
Alumina - - - -	11
Oxide of iron - - - -	3
Vegetable and saline matter - -	5
Moisture - - - -	3

I found the soil taken from a field at Sheffield Place in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter. And 100 parts of the entire soil submitted to analysis produced,

Silica - - - - -	54
Alumina - - - - -	28
Carbonate of lime - - - -	3
Oxide of iron - - - -	5
Decomposing vegetable matter - -	4
Moisture and loss - - - -	6

An excellent wheat soil from the neighbourhood of West Drayton, Middlesex, gave 3 parts in 5 of siliceous sand; and the finely divided matter consisted of

Carbonate of lime - - - -	28
Silica - - - - -	32
Alumina - - - - -	29
Animal or vegetable matter and moisture -	11

Of these soils the last was by far the most, and the first the least, coherent in texture. In all cases the constituent parts of the soil which give tenacity and coherence are the finely divided matters; and they possess the power of giving those qualities the highest degree when they contain much alumina. A small quantity of finely divided matter is sufficent to fit a soil for the production of turnips and barley; and I have seen a tolerable crop of turnips on a soil containing 11 parts out of 12 sand. A much greater proportion of sand, however, always produces absolute sterility. The soil of Bagshot Heath, which is entirely devoid of vegetable covering, contains less than $\frac{1}{20}$ of finely divided matter. 400 parts of it which had been heated red, afforded me 380 parts of coarse siliceous sand, 9 parts of fine siliceous sand, and 11 parts of impalpable matter, which was a mixture of ferruginous clay with carbonate of lime. Vegetable or animal matters, when finely divided, not only give coherence, but likewise softness and penetrability; but neither they nor any

other part of the soil must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matter.

Pure alumina, or silica, pure carbonate of lime, or carbonate of magnesia, are incapable of supporting healthy vegetation.

No soil is fertile that contains as much as 19 parts out of 20 of any of the constituents that have been mentioned.

It will be asked, are the pure earths in the soil merely active as mechanical, or indirect chemical agents, or do they actually afford food to the plant? This is an important question; and not difficult of solution.

The earths consist, as I have before stated, of metals, united to oxygen; and these metals have not been decomposed; there is consequently no reason to suppose that the earths are convertible into the elements of organized compounds, into carbon, hydrogen, and azote.

Plants have been made to grow in given quantities of earth. They consume very small portions only, and what is lost may be accounted for by the quantities found in their ashes; that is to say, it has not been converted into any new products.

The carbonic acid united to lime or magnesia, if any stronger acid happens to be formed in the soil during the fermentation of vegetable matter, which will disengage it from the earths, may be decomposed: but the earths themselves cannot be supposed convertible into other substances by any process taking place in the soil.

In all cases the ashes of plants contain some of the earths of the soil in which they grow; but these earths, as may be seen from the table of the ashes afforded by

different plants given in the last lecture, never equal more than $\frac{1}{50}$ of the weight of the plant consumed.

If they be considered as necessary to the vegetable, it is as giving hardness and firmness to its organization. Thus, it has been mentioned that wheat, oats, and many of the hollow grasses, have an epidermis principally of siliceous earth; the use of which seems to be to strengthen them, and defend them from the attacks of insects and parasitical plants.

Many soils are popularly distinguished as *cold;* and the distinction, though at first view it may appear to be founded on prejudice, is really just.

Some soils are much more heated by the rays of the sun, all other circumstances being equal, than others; and soils brought to the same degree of heat cool in different times, *i.e.* some cool much faster than others.

This property has been very little attended to in a philosophical point of view; yet it is of the highest importance in agriculture. In general, soils that consist principally of a stiff white clay are difficultly heated; and being usually very moist, they retain their heat only for a short time. *Chalks* are similar in one respect, that they are difficultly heated; but being drier they retain their heat longer, less being consumed in causing the evaporation of their moisture.

A black soil, containing much soft vegetable matter, is most heated by the sun and air; and the coloured soils, and the soils containing much carbonaceous matter, or ferruginous matter, exposed under equal circumstances to the sun, acquire a much higher temperature than pale-coloured soils.

When soils are perfectly dry, those that most readily become heated by the solar rays likewise cool most rapidly, their power of losing heat by radiation being

greatest; but I have ascertained, by experiment, that the darkest coloured dry soil, (that which contains abundance of animal or vegetable matter, substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of the effect of solar heat, will cool more slowly than a wet pale soil, entirely composed of earthy matter.

I found that a rich black mould, which contained nearly ¼ of the vegetable matter, had its temperature increased in an hour from 65° to 88° by exposure to sunshine; whilst a chalk soil was heated only to 69° under the same circumstances. But the mould removed into the shade, where the temperature was 62°, lost, in half an hour, 15°; whereas the chalk, under the same circumstances, had lost only 4°.

A brown fertile soil and a cold barren clay were each artificially heated to 88°, having been previously dried: they were then exposed in a temperature of 57°; in half an hour the dark soil was found to have lost 9° of heat; the clay had lost only 6°. An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a quarter of an hour, it was found to have gained the temperature of the room. The soils in all these experiments were placed in small tin-plate trays two inches square, and half an inch in depth, and the temperature ascertained by a delicate thermometer.

Nothing can be more evident than that the genial heat of the soil, particularly in spring, must be of the highest importance to the rising plant. And when the leaves are fully developed, the ground is shaded, and any injurious influence, which in the summer might be expected from too great a heat, entirely prevented; so

that the temperature of the surface, when bare and exposed to the rays of the sun, affords at least one indication of the degrees of its fertility; and the thermometer may be sometimes a useful instrument to the purchaser or improver of lands.

There is a very simple test of the cooling or radiating powers of soils, the formation of dew upon them, or their relative increase of weight by exposure to the air after being dried, in the day or the night, in sunshine or in shade. The soil that radiates most heat acquires the greatest increase of weight: and of course the radiating powers of the soil are not only connected with its temperature, but likewise with its relations to moisture.

The moisture in the soil influences its temperature; and the manner in which it is distributed through, or combined with, the earthy materials, is of great importance in relation to the nutriment of the plant. If water is too strongly attracted by the earths, it will not be absorbed by the roots of the plants; if it is in too great quantity, or too loosely united to them, it tends to injure or destroy the fibrous parts of the roots.

There are two states in which water seems to exist in the earths, and in animal and vegetable substances: in the first state it is united by chemical, in the other by cohesive, attraction.

If pure solution of ammonia or potassa be poured into a solution of alum, alumina falls down combined with water; and the powder dried by exposure to air will afford more than half its weight of water by distillation; in this instance the water is united by chemical attraction. The moisture which wood, or muscular fibre, or gum, that have been heated to 212°, afford by distillation at a red heat, is likewise water, the elements

of which were united in the substance by chemical combination.

When pipe-clay dried at the temperature of the atmosphere is brought in contact with water, the fluid is rapidly absorbed: this is owing to cohesive attraction. Soils in general, vegetable and animal substances, that have been dried at a heat below that of boiling water, increase in weight by exposure to air, owing to their absorbing water existing in the state of vapour in the air, in consequence of cohesive attraction.

The water *chemically combined* amongst the elements of soils, unless in the case of the decomposition of animal or vegetable substances, cannot be absorbed by the roots of plants; but that *adhering* to the parts of the soil is in constant use in vegetation. Indeed, there are few mixtures of the earths found in soils that contain any chemically combined water; water is expelled from the earths by most substances that combine with them. Thus, if a combination of lime and water be exposed to carbonic acid, the carbonic acid takes the place of water; and compounds of alumina and silica, or other compounds of the earths, do not chemically unite with water; and soils, as it has been stated, are formed either by earthy carbonates, or compounds of the pure earths and metallic oxides.

When saline substances exist in soils, they may be united to water both chemically and mechanically; but they are always in too small a quantity to influence materially the relations of the soil to water.

The power of the soil to absorb water by cohesive attraction depends in great measure upon the state of division of its parts; the more divided they are, the greater is their absorbent power. The different constituent parts of soils likewise appear to act, even by

cohesive attraction, with different degrees of energy. Thus vegetable substances seem to be more absorbent than animal substances; animal substances more so than compounds of alumina and silica; and compounds of alumina and silica more absorbent than carbonates of lime and magnesia: these differences may, however, possibly depend upon the differences in their state of division, and upon the surface exposed.

The power of soils to absorb water from air is much connected with fertility. When this power is great, the plant is supplied with moisture in dry seasons; and the effect of evaporation in the day is counteracted by the absorption of aqueous vapour from the atmosphere, by the interior parts of the soil during the day, and by both the exterior and interior during the night.

The stiff clays approaching to pipe-clays in their nature, which take up the greatest quantity of water when it is poured upon them in a fluid form, are not the soils which absorb most moisture from the atmosphere in dry weather. They cake, and present only a small surface to the air; and the vegetation on them is generally burnt up almost as readily as on sands.

The soils that are most efficient in supplying the plant with water by atmospheric absorption are those in which there is a due mixture of sand, finely divided clay, and carbonate of lime, with some animal or vegetable matter; and which are so loose and light as to be freely permeable to the atmosphere. With respect to this quality, carbonate of lime and animal and vegetable matter are of great use in soils; they give absorbent power to the soil without giving it likewise tenacity: sand, which also destroys tenacity, on the contrary, gives little absorbent power.

I have compared the absorbent powers of many soils

with respect to atmospheric moisture, and I have always found it greatest in the most fertile soils; so that it affords one method of judging of the productiveness of land.

1000 parts of a celebrated soil from Ormistown, in East Lothian, which contained more than half its weight of finely divided matter, of which 11 parts were carbonate of lime and 9 parts vegetable matter, when dried at 212°, gained in an hour by exposure to air saturated with moisture, at temperature 62°, 18 grains.

1000 parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances, gained 16 grains.

1000 parts of a soil from Mersea, in Essex, worth 45 shillings an acre, gained 13 grains.

1000 grains of a fine sand from Essex, worth 28 shillings an acre, gained 11 grains.

1000 of a coarse sand, worth 15 shillings an acre, gained only 8 grains.

1000 of the soil of Bagshot Heath, gained only 3 grains.

Water, and the decomposing animal and vegetable matter existing in the soil, constitute the true nourishment of plants; and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal or vegetable matter: when equally mixed with it, they prevent it from decomposing too rapidly; and by their means the soluble parts are supplied in proper proportions.

Besides this agency, which may be considered as mechanical, there is another agency between soils and organizable matters, which may be regarded as chemical

in its nature. The earths, and even the earthy carbonates, have a certain degree of chemical attraction for many of the principles of vegetable and animal substances. This is easily exemplified in the instance of alumina and oil; if an acid solution of alumina be mixed with a solution of soap, which consists of oily matter and potassa, the oil and the alumina will unite and form a white powder, which will sink to the bottom of the fluid.

The extract from decomposing vegetable matter, when boiled with pipe-clay or chalk, forms a combination by which the vegetable matter is rendered more difficult of decomposition and of solution. Pure silica and siliceous sands have little action of this kind; and the soils which contain the most alumina and carbonate of lime are those which act with the greatest chemical energy in preserving manures. Such soils merit the appellation which is commonly given to them of rich soils; for the vegetable nourishment is long preserved in them, unless taken up by the organs of plants. Siliceous sands, on the contrary, deserve the term hungry, which is commonly applied to them, for the vegetable and animal matters they contain not being attracted by the earthy constituent parts of the soil, are more liable to be decomposed by the action of the atmosphere, or carried off from them by water.

In most of the black and brown vegetable moulds, the earth seems to be in combination with a peculiar extractive matter, afforded during the decomposition of vegetables: this is slowly taken up, or attracted from the earths by water, and appears to constitute a prime cause of the fertility of the soil.

The standard of fertility of soils for different plants

must vary with the climate; and must be particularly influenced by the quantity of rain.

The power of soils to absorb moisture ought to be much greater in warm or dry countries than in cold or moist ones; and the quantity of clay, or vegetable or animal matter they contain, greater. Soils also on declivities ought to be more absorbent than in plains or in the bottom of valleys. Their productiveness likewise is influenced by the nature of the sub-soil or the stratum on which they rest.

When soils are immediately situated upon a bed of rock or stone, they are much sooner rendered dry by evaporation, than where the sub-soil is of clay or marl; and one cause of the great fertility of some lands in the moist climate of Ireland is the proximity of the rocky strata to the soil.

A clayey sub-soil will sometimes be of material advantage to a sandy soil; and in this case it will retain moisture in such a manner as to be capable of supplying that lost by the earth above, in consequence of evaporation, or the consumption of it by plants.

A sandy or gravelly sub-soil often corrects the imperfections of too great a degree of absorbent power in the true soil.

In calcareous countries, where the surface is a species of marl, the soil is often found only a few inches above the limestone; and its fertility is not impaired by the proximity of the rock: though in a less absorbent soil, this situation would occasion barrenness; and the sandstone and limestone hills in Derbyshire and North Wales may be easily distinguished at a distance in summer by the different tints of the vegetation. The grass on the sandstone hills usually appears brown and burnt up; that on the limestone hills, flourishing and green.

In devoting the different parts of an estate to the necessary crops, it is perfectly evident from what has been said that no general principle can be laid down, except when all the circumstances of the nature, composition, and situation of the soil and sub-soil are known.

The methods of cultivation likewise must be different for different soils. The same practice which will be excellent in one case may be destructive in another.

Deep ploughing may be a very profitable practice in a rich thick soil; and in a fertile shallow soil, situated upon cold clay or sandy sub-soil, it may be extremely prejudicial.

In a moist climate where the quantity of rain that falls annually equals from 40 to 60 inches, as in Lancashire, Cornwall, and some parts of Ireland, a siliceous sandy soil is much more productive than in dry districts; and in such situations, wheat and beans will require a less coherent and absorbent soil than in drier situations; and plants having bulbous roots will flourish in a soil containing as much as 14 parts out of 15 of sand.

Even the exhausting powers of crops will be influenced by like circumstances. In cases where plants cannot absorb sufficient moisture, they must take up more manure. And in Ireland, Cornwall, and the Western Highlands of Scotland, corn will exhaust less than in dry inland situations. Oats, particularly in dry climates, are impoverishing in a much higher degree than in moist ones.

Soils appear to have been originally produced in consequence of the decomposition of rocks and strata. It often happens, that soils are found in an unaltered state upon the rocks from which they were derived.

It is easy to form an idea of the manner in which rocks are converted into soils, by referring to the instance of *soft granite* or *porcelain granite*. This substance consists of three ingredients, quartz, feldspar, and mica. The quartz is almost pure siliceous earth, in a crystalline form. The feldspar and mica are very compounded substances; both contain silica, alumina, and oxide of iron: in the feldspar there is usually lime and potassa; in the mica, lime and magnesia.

When a granitic rock of this kind has been long exposed to the influence of air and water, the lime and the potassa contained in its constituent parts are acted upon by water or carbonic acid; and the oxide of iron, which is almost always in its least oxided state, tends to combine with more oxygen; the consequence is, that the feldspar decomposes, and likewise the mica, but the first the most rapidly. The feldspar, which is as it were the cement of the stone, forms a fine clay; the mica partially decomposed mixes with it as sand; and the undecomposed quartz appears as gravel, or sand of different degrees of fineness.

As soon as the smallest layer of earth is formed on the surface of a rock, the seeds of lichens, mosses, and other imperfect vegetables which are constantly floating in the atmosphere; and which have made it their resting-place, begin to vegetate: their death, decomposition, and decay, afford a certain quantity of organizable matter, which mixes with the earthy materials of the rock; in this improved soil more perfect plants are capable of subsisting; these in their turn absorb nourishment from water and the atmosphere; and after perishing, afford new materials to those already provided: the decomposition of the rock still continues; and at length, by such slow and

gradual processes, a soil is formed in which even forest trees can fix their roots, and which is fitted to reward the labours of the cultivator.

In instances where successive generations of vegetables have grown upon a soil, unless part of their produce has been carried off by man, or consumed by animals, the vegetable matter increases in such a proportion that the soil approaches to a peat in its nature; and if in a situation where it can receive water from a higher district, it becomes spongy, and permeated with that fluid, and is gradually rendered incapable of supporting the nobler classes of vegetables.

Many peat-mosses seem to have been formed by the destruction of forests, in consequence of the imprudent use of the hatchet by the early cultivators of the country in which they exist: when the trees are felled in the outskirts of a wood, those in the interior, exposed to the influence of the winds, and having been accustomed to shelter, become unhealthy, and die in their new situation; and their leaves and branches gradually decomposing, produce a stratum of vegetable matter. In many of the great bogs in Ireland and Scotland, the larger trees that are found in the outskirts of them bear the marks of having been felled. In the interior few entire trees are found; and the cause is, probably, that they fell by gradual decay; and that the fermentation and decomposition of the vegetable matter was most rapid where it was in the greatest quantity.

Lakes and pools of water are sometimes filled up by the accumulation of the remains of aquatic plants; and in this case a sort of spurious peat is formed. The fermentation in these cases, however, seems to be of a different kind. Much more gaseous matter is evolved; and the neighbourhood of morasses in which aquatic

vegetables decompose is usually aguish and unhealthy; whilst that of the true peat, or peat formed on soils originally dry, is always salubrious.

The earthy matter of peats is uniformly analogous to that of the stratum on which they repose; the plants which have formed them, must have derived the earths that they contained from this stratum. Thus, in Wiltshire and Berkshire, where the stratum below the peat is chalk, calcareous earth abounds in the ashes, and very little alumina and silica. They likewise contain much oxide of iron and gypsum, both of which may be derived from the decomposition of the pyrites, so abundant in chalk.

Different specimens of peat that I have burnt from the granitic and schistose soils of different parts of these islands, have always given ashes, principally siliceous and aluminous; and a specimen of peat from the county of Antrim, gave ashes which afforded very nearly the same constituents as the great basaltic stratum of the county.

Poor and hungry soils, such as are produced from the decomposition of granitic and sandstone rocks, remain very often for ages with only a thin covering of vegetation. Soils from the decomposition of limestone, chalks, and basalts, are often clothed by nature with the perennial grasses; and afford, when ploughed up, a rich bed for the vegetation of every species of cultivated plant.

Rocks and strata, from which soils have been derived, and those which compose the more interior solid parts of the globe, are arranged in a certain order; and as it often happens that strata very different in their nature are associated together, and that the strata immediately beneath the soil contain materials which may be of use for improving it, a general view of the nature and posi-

tion of rocks and strata in nature, will not, I trust, be unacceptable to the scientific farmer.

Rocks are generally divided by geologists into two grand divisions, distinguished by the names of *primary* and *secondary*.

The primary rocks are composed of pure crystalline matter, and contain no fragments of other rocks.

The secondary rocks, or strata, consist only partly of crystalline matter, contain fragments of other rocks or strata; often abound in remains of vegetables and marine animals; and sometimes contain the remains of land animals.

The primary rocks are generally arranged in large masses, or in layers, vertical, or more or less inclined to the horizon.

The secondary rocks are usually disposed in strata or layers, parallel, or nearly parallel, to the horizon.

The number of primary rocks which are commonly observed in nature, are eight.

First, *granite*, which, as has been mentioned, is composed of quartz, feldspar, and mica; when these bodies are arranged in regular layers in the rock, it is called *gneis*.

Second, *micaceous schistus*, which is composed of quartz and mica, arranged in layers, which are usually curvilineal.

Third, *sienite*, which consists of the substance called hornblende and feldspar.

Fourth, *serpentine*, which is constituted by feldspar, and a body named resplendent hornblende; and their separate crystals are often so small, as to give the stone a uniform appearance: this rock abounds in veins of a substance called *steatite*, or *soap-rock*.

Fifth, *porphyry*, which consists of crystals of feldspar,

embedded in the same material, but usually of a different colour.

Sixth, *granular marble*, which consists entirely of crystals of carbonate of lime; and which, when its colour is white, and texture fine, is the substance used by statuaries.

Seventh, *chlorite schist*, which consists of chlorite, a green or grey substance, somewhat analogous to mica and feldspar.

Eighth, *quartzose rock*, which is composed of quartz in a granular form, sometimes united to small quantities of the crystalline elements, which have been mentioned as belonging to the other rocks.

The secondary rocks are more numerous than the primary; but twelve varieties include all that are usually found in these islands.

First, *grauwacke*, which consists of fragments of quartz, or chlorite schist, embedded in a cement, principally composed of feldspar.

Second, *siliceous sandstone*, which is composed of fine quartz or sand, united by a siliceous cement.

Third, *limestone*, consisting of carbonate of lime, more compact in its texture, than in the granular marble; and often abounding in marine exuviæ.

Fourth, *aluminous schist* or *shale*, consisting of the decomposed materials of different rocks, cemented by a small quantity of ferruginous or siliceous matter; and often containing the impressions of vegetables.

Fifth, *calcareous sandstone*, which is calcareous sand, cemented by calcareous matter.

Sixth, *ironstone*, formed of nearly the same materials as aluminous schist or shale; but containing a much larger quantity of oxide of iron.

Seventh, *basalt*, or *whinstone*, which consists of feld-

spar and hornblende, with materials derived from the decomposition of the primary rocks; the crystals are generally so small, as to give the rock a homogeneous appearance; and it is often disposed in very regular columns, having usually five or six sides.

Eighth, *bituminous* or *common coal.*

Ninth, *gypsum,* the substance so well known by that name, which consists of sulphate of lime; and often contains sand.

Tenth, *rock-salt.*

Eleventh, *chalk,* which usually abounds in remains of marine animals, and contains horizontal layers of flints.

Twelfth, *plum-pudding stone,* consisting of pebbles cemented by a ferruginous or siliceous cement.

To describe more particularly the constituent parts of the different rocks and strata, will be unnecessary; at any time, indeed, details on this subject are useless, unless the specimens are examined by the eye; and a close inspection and comparison of the different species, will, in a short time, enable the most common observer to distinguish them.

The highest mountains in these islands, and, indeed, in the whole of the old continent, are constituted by granite; and this rock has likewise been found at the greatest depths to which the industry of man has as yet been able to penetrate; micaceous schist is often found immediately upon granite; serpentine or marble upon micaceous schist; but the order in which the primary rocks are grouped together, is various. Marble and serpentine are usually found uppermost; but granite, though it seems to form the foundation of the rocky strata of the globe, is yet sometimes discovered above micaceous schist.

The secondary rocks are always incumbent on the primary; the lowest of them is usually grauwacke; upon this limestone or sandstone is often found; coal generally occurs between sandstone or shale: basalt often exists above sandstone and limestone; rock-salt almost always occurs associated with red sandstone and gypsum. Coal, basalt, sandstone, and limestone, are often arranged in different alternate layers, of no considerable thickness, so as to form a great extent of country. In a depth of less than 500 yards, 80 of these different alternate strata have been counted.

The veins which afford metallic substances, are fissures vertical, or more or less inclined, filled with a material different from the rock in which they exist. This material is almost always crystalline; and usually consists of calcareous spar, fluor spar, quartz, or heavy spar, either separate or together. The metallic substances are generally dispersed through, or confusedly mixed, with these crystalline bodies. The veins in hard granite, seldom afford much useful metal; but in the veins in soft granite, and in gneis, tin, copper, and lead are found. Copper and iron are the only metals usually found in the veins in serpentine. Micaceous schist, sienite, and granular marble, are seldom metalliferous rocks. Lead, tin, copper, iron, and many other metals, are found in the veins in chlorite schist. Grauwacke, when it contains few fragments, and exists in large masses, is often a metalliferous rock. The precious metals, likewise iron, lead, and antimony, are found in it; and sometimes it contains veins, or masses of *stone coal*, or coal free from bitumen. Limestone is the great metalliferous rock of the secondary family; and lead and copper are the metals most usually found in it. No metallic veins have ever been found in shale, chalk, or cal-

1 Granite
2 Gneis
3 Micaceous Sh
4 Sienite
5 Serpentine
6 Porphyry

ıreous sandstone; and they are very rare in basalt and liceous sandstone.*

In cases where veins in rocks are exposed to the atnosphere, indications of the metals they contain may be ›ften gained, from their superficial appearance. Whenever fluor spar is found in a vein, there is always strong reason to suspect that it is associated with metallic substances. A brown powder at the surface of a vein, always indicates iron, and often tin; a pale yellow powder, lead; and a green colour in a vein, denotes the presence of copper.

It may not be improper to give a general description of the geological constitution of Great Britain and Ireland. Granite forms the great ridge of hills extending from Land's End through Dartmore into Devonshire. The highest rocky strata in Somersetshire are grauwacke and limestone. The Malvern hills are composed of granite, sienite, and porphyry. The highest mountains in Wales are chlorite schist, or grauwacke. Granite occurs at Mount Sorrel, in Leicestershire. The great range of the mountains in Cumberland, and Westmoreland are porphyry, chlorite, schist and grauwacke; but granite is found as their western boundary. Throughout Scotland the most elevated rocks are granite, sienite, and micaceous schistus. No true secondary formations are found in South Britain, west of Dartmore; and no basalt south of the Severn. The chalk district extends from the western part of Dorsetshire to the eastern coast of Norfolk. The coal formations abound in the district between Glamorganshire and Derbyshire; and likewise in the secondary strata of Yorkshire, Durham, Westmoreland, and Northumber-

* Fig. 16. will give a general idea of the appearance and arrangement of rocks and veins.

land. Serpentine is found only in three places in Great Britain; near Cape Lizard in Cornwall, Portsoy in Aberdeenshire, and in Ayrshire. Black and grey granular marble is found near Padstow in Cornwall; and other coloured primary marbles exist in the neighbourhood of Plymouth. Coloured primary marbles are abundant in Scotland; and white granular marble is found in the Isle of Sky, in Assynt, and on the banks of Loch Shin in Sutherland: the principal coal formations in Scotland are in Dumbartonshire, Ayrshire, Fifeshire, and on the banks of the Brora, in Sutherland. Secondary limestone and sandstone are found in most of the low countries north of the Mendip hills.

In Ireland there are five great associations of primary mountains; the mountains of Morne, in the county of Down; the mountains of Donegal; those of Mayo and Galway; those of Wicklow; and those of Kerry. The rocks composing the four first of these mountain chains are principally granite, gneis, sienite, micaceous schist, and porphyry. The mountains of Kerry are chiefly constituted by granular quartz, and chlorite schist. Coloured marble is found near Killarney; and white marble on the western coast of Donegal.

Limestone and sandstone are the common secondary rocks found south of Dublin. In Sligo, Roscommon, and Leitrim, limestone, sandstone, shale, ironstone, and bituminous coal are found. The secondary hills in these counties are of considerable elevation; and many of them have basaltic summits. The north coast of Ireland is principally basalt; this rock commonly reposes upon a white limestone, containing layers of flint, and the same fossils as chalk; but it is considerably harder than that rock. There are some instances, in this district, in which columnar basalt is found above

sandstone and shale, alternating with coal. The stone-coal of Ireland is principally found in Kilkenny, associated with limestone and grauwacke.

It is evident from what has been said concerning the production of soils from rocks, that there must be at least as many varieties of soils as there are species of rocks exposed at the surface of the earth; in fact there are many more. Independent of the changes produced by cultivation and the exertions of human labour, the materials of strata have been mixed together and transported from place to place by various great alterations that have taken place in the system of our globe, and by the constant operation of water.

To attempt to class soils with scientific accuracy would be a vain labour; the distinctions adopted by farmers are sufficient for the purposes of agriculture; particularly if some degree of precision be adopted in the application of terms. The term sandy, for instance, should never be applied to any soil that does not contain at least $\frac{7}{8}$ of sand; sandy soils that effervesce with acids should be distinguished by the name of calcareous sandy soil, to distinguish them from those that are siliceous. The term clayey soil should not be applied to any land which contains less than $\frac{1}{6}$ of impalpable earthy matter, not considerably effervescing with acids: the word loam should be limited to soils containing at least one-third of impalpable earthy matter, copiously effervescing with acids. A soil, to be considered as peaty, ought to contain at least one-half of vegetable matter.

In cases where the earthy part of a soil evidently consists of a decomposed matter of one particular rock, a name derived from the rock may with propriety be applied to it. Thus, if a fine red earth be found im-

mediately above decomposing basalt, it may be denominated basaltic soil. If fragments of quartz and mica be found abundant in the materials of the soil, which is often the case, it may be denominated granitic soil; and the same principles may be applied to other like instances.

In general, the soils, the materials of which are the most various and heterogeneous, are those called alluvial, or which have been formed from the depositions of rivers; many of them are extremely fertile. I have examined some productive alluvial soils, which have been very different in their composition. The soil which has been mentioned page 326 as very productive, from the banks of the river Parret in Somersetshire, afforded me eight parts of finely divided earthy matter, and one part of siliceous sand; and an analysis of the finely divided matter gave the following results:—

360	parts of	carbonate of lime.
25	—	alumina.
20	—	silica.
8	—	oxide of iron.
19	—	vegetable, animal, and saline matter.

A rich soil from the neighbourhood of the Avon, in the valley of Evesham in Worcestershire, afforded me three-fifths of fine sand, and two-fifths of impalpable matter; the impalpable matter consisted of,

35	Alumina.
41	Silica.
14	Carbonate of lime.
3	Oxide of iron.
7	Vegetable, animal, and saline matter.

A specimen of good soil from Tiviot-dale, afforded

five-sixths of fine siliceous sand, and one-sixth of impalpable matter; which consisted of

41 Alumina.
42 Silica.
4 Carbonate of lime.
5 Oxide of iron.
8 Vegetable, animal, and saline matter.

A soil yielding excellent pasture from the valley of the Avon, near Salisbury, afforded one-eleventh of coarse siliceous sand; and the finely divided matter consisted of

7 Alumina.
14 Silica.
63 Carbonate of lime.
2 Oxide of iron.
14 Vegetable, animal, and saline matter.

In all these instances the fertility seems to depend upon the state of division, and mixture of the earthy materials and the vegetable and animal matter; and may be easily explained on the principles which I have endeavoured to elucidate in the preceding part of this Lecture.

In ascertaining the composition of sterile soils with a view to their improvement, any particular ingredient which is the cause of their unproductiveness, should be particularly attended to; if possible, they should be compared with fertile soils in the same neighbourhood, and in similar situations, as the difference of the composition may, in many cases, indicate the most proper methods of improvement. If on washing a sterile soil it is found to contain the salt of iron, or any acid matter, it may be ameliorated by the application of quicklime. A soil of good apparent texture from Lincolnshire, was put into my hands by Sir Joseph Banks

as remarkable for sterility. On examining it, I found that it contained sulphate of iron; and I offered the obvious remedy of top-dressing with lime, which converts the sulphate into a manure. If there be an excess of calcareous matter in the soil, it may be improved by the application of sand, or clay. Soils too abundant in sand are benefited by the use of clay or marl, or vegetable matter. A field belonging to Sir Robert Vaughan at Nannau, Merionethshire, the soil of which was a light sand, was much burnt up in the summer of 1805; I recommended to that gentleman the application of peat as a top-dressing. The experiment was attended with immediate good effects; and Sir Robert has informed me, that the benefit was permanent. A deficiency of vegetable or animal matter must be applied by manure. An excess of vegetable matter is to be removed by burning, or to be remedied by the application of earthy materials. The improvement of peats, or bogs, or marsh lands, must be preceded by draining; stagnant water being injurious to all the nutritive classes of plants. Soft black peats, when drained, are often made productive by the mere application of sand or clay as a top-dressing. When peats are acid, or contain ferruginous salts, calcareous matter is absolutely necessary in bringing them into cultivation. When they abound in the branches and roots of trees, or when their surface entirely consists of living vegetables, the wood or the vegetables must either be carried off, or be destroyed by burning. In the last case their ashes afford earthy ingredients, fitted to improve the texture of the peat.

The best natural soils are those of which the materials have been derived from different strata; which have been minutely divided by air and water, and are inti-

mately blended together; and in improving soils artificially, the farmer cannot do better than imitate the processes of nature.

The materials necessary for the purpose are seldom far distant: coarse sand is often found immediately on chalk; and beds of sand and gravel are common below clay. The labour of improving the texture or constitution of the soil is repaid by a great permanent advantage; less manure is required, and its fertility insured. And capital laid out in this way secures, for ever, the productiveness, and consequently the value, of the land.

LECTURE V.

On the Nature and Constitution of the Atmosphere, and its Influence on Vegetables.—Of the Germination of Seeds.—Of the Functions of Plants in their different Stages of Growth; with a General View of the Progress of Vegetation.

The constitution of the atmosphere has been already generally referred to in the preceding Lectures. Water, carbonic acid gas, oxygen, and azote, have been mentioned as the principal substances composing it; but more minute inquiries respecting their nature and agencies, are necessary to afford correct views of the uses of the atmosphere in vegetation.

On these inquiries I now propose to enter; the pursuit of them, I hope, will offer some objects of practical use in farming; and present some philosophical illustrations of the manner in which plants are nourished, their organs unfolded, and their functions developed.

If some of the salt, called muriate of lime, that has been just heated red, be exposed to the air, even in the driest and coldest weather, it will increase in weight, and become moist; and, in a certain time, will be converted into a fluid. If put into a retort and heated, it will yield pure water; will gradually recover its pristine state; and, if heated red, its former weight: so that it is evident that the water united to it was derived from the air. And that it existed in the air in an invisible and elastic form, is proved by the circumstance, that if a given quantity of air be exposed to the salt, its volume

and weight will diminish, provided the experiment be correctly made.

The quantity of water which exists in air, as vapour, varies with the temperature. In proportion as the weather is hotter, the quantity is greater.

At 50° of Fahrenheit, air contains about $\frac{1}{50}$ of its volume of vapour; and as the specific gravity of vapour is to that of air nearly as 10 to 15, this is about $\frac{1}{75}$ of its weight.

At 100°, supposing that there is a free communication with water, it contains about $\frac{1}{14}$ part in volume, or $\frac{1}{21}$ in weight. It is the condensation of vapour by diminution of the temperature of the atmosphere, which is probably the principal cause of the formation of clouds, and of the deposition of dew, mist, snow, or hail.

The power of different substances to absorb aqueous vapours from the atmosphere, by cohesive attraction, was discussed in the last Lecture. The leaves of living plants appear to act upon the vapour, likewise, in its elastic form, and to absorb it. Some vegetables increase in weight from this cause, when suspended in the atmosphere, and unconnected with the soil; such are the houseleek, and different species of the aloe. In very intense heats, and when the soil is dry, the life of plants seems to be preserved by the absorbent power of their leaves: and it is a beautiful circumstance in the economy of nature, that aqueous vapour is most abundant in the atmosphere when it is most needed for the purpose of life; and that when other sources of its supply are cut off, this is most copious.

The compound nature of water has been referred to. It may be proper to mention the experimental proofs of its decomposition into, and composition from, oxygen, and hydrogen.

If the metal called potassium be exposed in a glass tube to a small quantity of water, it will act upon it with great violence; elastic fluid will be disengaged, which will be found to be hydrogen; and the same effects will be produced upon the potassium as if it had absorbed a small quantity of oxygen; and the hydrogen disengaged, and the oxygen added to the potassium, are in weight as 2 to 15; and if two in volume of hydrogen, and one in volume of oxygen, which have the weights of 2 and 15, be introduced into a close vessel, and an electrical spark passed through them, they will inflame and condense into 17 parts of pure water.

It is evident from the statements given in the third Lecture, that water forms by far the greatest part of the sap of plants; and that this substance, or its elements, enters largely into the constitution of their organs and solid productions.

Water is absolutely necessary to the economy of vegetation in its elastic and fluid state; and it is not devoid of use even in its solid form. Snow and ice are bad conductors of heat; and when the ground is covered with snow, or the surface of the soil or of water is frozen, the roots or bulbs of the plants beneath are protected by the congealed water from the influence of the atmosphere, the temperature of which in northern winters is usually very much below the freezing point; and this water becomes the first nourishment of the plant in early spring. The expansion of water during its congelation, at which time its volume increases $\frac{1}{12}$, and its contraction of bulk during a thaw, tend to pulverise the soil; to separate its parts from each other, and to make it more permeable to the influence of the air.

If a solution of lime in water be exposed to the air, a pellicle will speedily form upon it, and a solid matter

will gradually fall to the bottom of the water, and in a certain time the water will become tasteless; this is owing to the combination of the lime, which was dissolved in the water with carbonic acid gas which existed in the atmosphere, as may be proved by collecting the film and the solid matter, and igniting them strongly in a little tube of platina or iron: they will give off carbonic acid gas, and will become quicklime, which, added to the same water, will again bring it to the state of lime-water.

The quantity of carbonic acid gas in the atmosphere is very small. It is not easy to determine it with precision, and it must differ in different situations; but where there is a free circulation of air, it is probably never more than $\frac{1}{500}$, nor less than $\frac{1}{800}$ of the volume of air. Carbonic acid gas is nearly $\frac{1}{3}$ heavier than the other elastic parts of the atmosphere in their mixed state: hence, at first view, it might be supposed that it would be most abundant in the lower regions of the atmosphere; but unless it has been immediately produced at the surface of the earth in some chemical process, this does not seem to be the case: elastic fluids of different specific gravities have a tendency to equable mixture by a species of attraction, and the different parts of the atmosphere are constantly agitated and blended together by winds or other causes. De Saussure found lime-water precipitated on Mount Blanc, the highest point of land in Europe; and carbonic acid gas has been always found, apparently in due proportion, in the air brought down from great heights in the atmosphere by aërostatic adventurers.

The experimental proofs of the composition of carbonic acid gas are very simple. If 13 grains of well burnt charcoal be inflamed by a burning-glass in 100

cubical inches of oxygen gas, the charcoal will entirely disappear; and, provided the experiment be correctly made, all the oxygen, except a few cubical inches, will be found converted into carbonic acid; and, what is very remarkable, the volume of the gas is not changed. On this last circumstance it is easy to found a correct estimation of the quantity of pure charcoal and oxygen in carbonic acid gas: the weight of 100 cubical inches of carbonic acid gas is to that of 100 cubical inches of oxygen gas, as 47 to 34: so that 47 parts in weight of carbonic acid gas must be composed of 34 parts of oxygen and 13 of charcoal, which correspond with the numbers given in the second Lecture.

Carbonic acid is easily decomposed by heating potassium in it; the metal combines with the oxygen, and the charcoal is deposited in the form of a black powder.

The principal consumption of the carbonic acid in the atmosphere, seems to be in affording nourishment to plants; and some of them appear to be supplied with carbon chiefly from this source.

Carbonic acid gas is formed during fermentation, combustion, putrefaction, respiration, and a number of operations taking place upon the surface of the earth; and there is no other process known in nature by which it can be destroyed but by vegetation.

After a given portion of air has been deprived of aqueous vapour and carbonic acid gas, it appears little altered in its properties; it supports combustion and animal life. There are many modes of separating its principal constituents, oxygen, and azote, from each other. A simple one is by burning phosphorus in a confined volume of air: this absorbs the oxygen and leaves the azote; and 100 parts in volume of air in which phosphorus has been burnt, yield 79 parts of

azote; and by mixing this azote with 21 parts of fresh oxygen gas artificially procured, a substance having the original characters of air is produced. To procure pure oxygen from air, quicksilver may be kept heated in it, at about 600°, till it becomes a red powder: this powder, when ignited, will be restored to the state of quicksilver by giving off oxygen.

Oxygen is necessary to some functions of vegetables, but its great importance in nature is in its relation to the economy of animals. It is absolutely necessary to their life. Atmospheric air taken into the lungs of animals, or passed in solution in water through the gills of fishes, loses oxygen; and for the oxygen lost, about an equal volume of carbonic acid appears.

The effects of azote in vegetation are not distinctly known. As it is found in some of the products of vegetation, it may be absorbed by certain plants from the atmosphere. It prevents the action of oxygen from being too energetic, and serves as a medium in which the more essential parts of the air act: nor is this circumstance unconformable to the analogy of nature; for the elements most abundant on the solid surface of the globe, are not those which are the most essential to the existence of the living beings belonging to it.

The action of the atmosphere on plants differs at different periods of their growth, and varies with the various stages of the developement and decay of their organs. Some general idea of its influence may have been gained from circumstances already mentioned: I shall now refer to it more particularly, and endeavour to connect it with a general view of the progress of vegetation.

If a healthy seed be moistened and exposed to air at a temperature not below 45°, it soon germinates; it

shoots forth a plume which rises upwards, and a radicle which descends.

If the air be confined, it is found that in the process of germination the oxygen, or a part of it, is absorbed. The azote remains unaltered; no carbonic acid is taken away from the air; on the contrary, some is added.

Seeds are incapable of germinating, except when oxygen is present. In the exhausted receiver of the air-pump, in pure azote, in pure carbonic acid, when moistened they swell, but do not vegetate; and if kept in these gases, lose their living powers, and undergo putrefaction.

If a seed be examined before germination, it will be found more or less insipid, at least not sweet; but after germination it is always sweet. Its coagulated mucilage, or starch, is converted into sugar in the process; a substance difficult of solution is changed into one easily soluble; and the sugar carried through the cells or vessels of the cotyledons, is the nourishment of the infant plant. It is easy to understand the nature of the change, by referring to the facts mentioned in the third Lecture; and the production of carbonic acid renders probable the idea, that the principal chemical difference between sugar and mucilage depends upon the sugar containing a larger proportion of the elements of water, and upon a slight difference in the proportions of their carbon.

The absorption of oxygen by the seed in germination, has been compared to its absorption in producing the evolution of fœtal life in the egg; but this analogy is only remote. All animals, from the most to the least perfect classes, require a supply of oxygen.* From the

* The impregnated eggs of insects, and even of fishes, do not produce young ones, unless they are supplied with air, that is,

moment the heart begins to pulsate till it ceases to beat, the aëration of the blood is constant, and the function of respiration invariable; carbonic acid is given off in the process, but the chemical change produced in the blood is unknown; nor is there any reason to suppose the formation of any substance similar to sugar. In the production of a plant from a seed, some reservoir of nourishment is needed before the root can supply sap; and this reservoir is the cotyledon, in which it is stored up in an insoluble form, and protected, if necessary during the winter, and rendered soluble by agents which are constantly present on the surface. The change of starch into sugar, connected with the absorption of oxygen, may be rather compared to a process of fermentation than to that of respiration; it is a change effected upon unorganized matter, and can be artificially imitated; and in most of the chemical changes that occur when vegetable compounds are exposed to air, oxygen is absorbed, and carbonic acid formed or evolved.

unless the fœtus can respire. I have found that the eggs of moths did not produce larvæ when confined in pure carbonic acid; and when they were exposed in common air, the oxygen partly disappeared, and carbonic acid was formed. The fish in the egg or spawn gains its oxygen from the air dissolved in water; and those fishes that spawn in spring and summer in still water, such as pike, carp, perch and bream, deposit their eggs upon subaquatic vegetables, the leaves of which, in performing their healthy functions, supply oxygen to the water. The fish that spawn in winter, such as salmon and trout, seek spots where there is a constant supply of fresh water, as near the sources of streams as possible, and in the most rapid currents, where all stagnation is prevented, and where the water is saturated with air, to which it has been exposed during its deposition from the clouds. It is the instinct leading these fish to seek a supply of air for their eggs which carries them from seas or lakes into the mountain country, which induces them to move against the stream, and to endeavour to overleap weirs, mill-dams, and cataracts.

It is evident, that in all cases of tillage the seeds should be sown so as to be fully exposed to the influence of the air. And one cause of the unproductiveness of cold clayey adhesive soils is, that the seed is coated with matter impermeable to air.

In sandy soils the earth is always sufficiently penetrable by the atmosphere; but in clayey soils there can scarcely be too great a mechanical division of parts in the process of tillage. Any seed not fully supplied with air, always produces a weak and diseased plant.

The process of malting, which has been already referred to, is merely a process in which germination is artificially produced; and in which the starch of the cotyledon is changed into sugar; which sugar is afterwards, by fermentation, converted into spirit.

It is very evident from the chemical principles of germination, that the process of malting should be carried on no further than to produce the sprouting of the radicle, and should be checked as soon as this has made its distinct appearance. If it is pushed to such a degree as to occasion the perfect development of the radicle and the plume, a considerable quantity of saccharine matter will have been consumed in producing their expansion, and there will be less spirit formed in fermentation, or produced in distillation.

As this circumstance is of some importance, I made in October, 1806, an experiment relating to it. I ascertained by the action of alcohol, the relative proportions of saccharine matter in two equal quantities of the same barley; in one of which the germination had proceeded so far as to occasion a protrusion of the radicle to nearly a quarter of an inch beyond the grain in most of the specimens, and in the other of which it had been checked before the radicle was a line in

length; the quantity of sugar afforded by the last was to that in the first nearly as six to five.

The saccharine matter in the cotyledons at the time of their change into seed-leaves, renders them exceedingly liable to the attacks of insects: this principle is at once a nourishment of plants and animals, and the greatest ravages are committed upon crops in this first stage of their growth.

The turnip fly, an insect of the coleoptera genus, fixes itself upon the seed-leaves of the turnip at the time that they are beginning to perform their functions; and when the rough leaves of the plume are thrown forth, it is incapable of injuring the plant to any extent.

Several methods have been proposed for destroying the turnip fly, or for preventing it from injuring the crop. It has been proposed to sow radish-seed with the turnip-seed, on the idea that the insect is fonder of the seed-leaves of the radish than those of the turnip: it is said that this plan has not been successful, and that the fly feeds indiscriminately on both.

There are several chemical menstrua which render the process of germination much more rapid, when the seeds have been steeped in them. As in these cases the seed-leaves are quickly produced, and more speedily perform their functions, I proposed it as a subject of experiment to examine whether such menstrua might not be useful in raising the turnip more speedily to that state in which it would be secure from the fly; but the result proved that the practice was inadmissible; for seeds so treated, though they germinated much quicker did not produce healthy plants, and often died soon after sprouting.

I steeped radish-seeds in September, 1807, for twelve hours in a solution of chlorine, and similar seeds in

very diluted nitric acid, in very diluted sulphuric acid, in weak solution of oxysulphate of iron, and some in common water. The seeds in solutions of chlorine and oxysulphate of iron threw out the germ in two days, those in nitric acid in three days, in sulphuric acid in five, and those in water in seven days. But in the cases of premature germination, though the plume was very vigorous for a short time, yet it became at the end of a fortnight weak and sickly; and at that period less vigorous in its growth than the sprouts which had been naturally developed, so that there can be scarcely any useful application of these experiments. Too rapid growth and premature decay seem invariably connected in organized structures; and it is only by following the slow operations of natural causes, that we are capable of making improvements.

There is a number of chemical substances which are very offensive and even deadly to insects, which do not injure, and some of which even assist vegetation. Several of these mixtures have been tried with various success; a mixture of sulphur and lime, which is very destructive to slugs, does not prevent the ravages of the fly on the young turnip crop. His Grace the Duke of Bedford, at my suggestion, was so good as to order the experiment to be tried on a considerable scale at Woburn farm; the mixture of lime and sulphur was strewed over one part of a field sown with turnips; nothing was applied to the other part, but both were attacked nearly in the same manner by the fly.

Mixtures of soot and quicklime, and urine and quicklime, will probably be more efficacious. The volatile alkali given off by these mixtures is offensive to insects; and they afford nourishment to the plant. Mr. T. A. Knight informs me, that he has tried the method by

ammoniacal fumes with success; but more extensive trials are necessary to establish its general efficacy.* It may, however, be safely adopted; for if it should fail in destroying the fly, it will at least be a useful manure to the land.

After the roots and leaves of the infant plant are formed, the cells and tubes throughout its structure become filled with fluid, which is usually supplied from

* Mr. Knight has been so good as to furnish me with the following note on this subject.

"The experiment which I tried the year before last, and last year, to preserve turnips from the fly, has not been sufficiently often repeated to enable me to speak with any degree of decision; and last year all my turnips succeeded perfectly well. In consequence of your suggestion, when I had the pleasure to meet you some years ago at Holkham, that lime slaked with urine might possibly be found to kill, or drive off, the insects from a turnip crop, I tried that preparation in mixture with three parts of soot, which was put into a small barrel, with gimblet holes round it, to permit a certain quantity of the composition, about four bushels to an acre, to pass out and to fall into the drills with the turnip seeds. Whether it was by affording highly stimulating food to the plant, or giving some flavour which the flies did not like, I cannot tell; but in the year 1811, the adjoining rows were eaten away, and those to which the composition was applied, as above described, were scarcely at all touched. It is my intention in future to drill my crop in, first with the composition on the top of the ridge; and then to sow at least a pound of seed, broad-cast, over the whole ground. The expense of this will be very trifling, not more than 2*s*. per acre; and the horse-hoe will instantly sweep away all supernumeraries between the rows, should those escape the flies, to which, however, they will be chiefly attracted; because it it will always be found that those insects prefer turnips growing in poor to those in rich ground. One advantage seems to be the acceleration given to the growth of the plants, by the highly stimulative effects of the food they instantly receive, as soon as their growth commences, and long before their radicles have reached the dung. The directions above given apply only to turnips sowed upon ridges, with the manure immediately under them: and I am quite certain, that in all soils turnips should be thus cultivated. The close vicinity of the manure, and the consequent short time required to carry the food into the leaf, and return the organizable matter to the roots, are, in my hypothesis, points of vast importance; and the results in practice are correspondent."

the soil, and the function of nourishment is performed by the action of its organ upon the external elements. The constituent parts of the air are subservient to this process; but, as it might be expected, they act differently under different circumstances.

When a growing plant, the roots of which are supplied with proper nourishment, is exposed in the presence of solar light to a given quantity of atmospherical air, containing its due proportion of carbonic acid, the carbonic acid after a certain time is destroyed, and a certain quantity of oxygen is found in its place. If new quantities of carbonic acid gas be supplied, the same result occurs; so that carbon is added to plants from the air by the process of vegetation in sunshine; and oxygen is added to the atmosphere.

This circumstance is proved by a number of experiments made by Drs. Priestley, Ingenhousz, and Woodhouse, and M. T. de Saussure; many of which I have repeated with similar results. The absorption of carbonic acid gas and the production of oxygen are performed by the leaf; and leaves recently separated from the tree effect the change, when confined in portions of air containing carbonic acid; and absorb carbonic acid and produce oxygen even when immersed in water holding carbonic acid in solution.

The carbonic acid is probably absorbed by the fluids in the cells of the green or parenchymatous part of the leaf; and it is from this part that oxygen gas is produced during the presence of light. M. Sennebier found that the leaf, from which the epidermis was stripped off, continued to produce oxygen when placed in water containing carbonic acid gas, and the globules of air rose from the denuded parenchyma; and it is shown both from the experiments of Sennebier and

Woodhouse, that the leaves most abundant in parenchymatous parts produce most oxygen in water impregnated with carbonic acid.

Some few plants* will vegetate in an artificial atmosphere, consisting principally of carbonic acid, and many will grow for some time in air containing from one-half to one-third; but they are not so healthy as when supplied with smaller quantities of this elastic substance.

Plants exposed to light have been found to produce oxygen gas in an elastic medium, and in water containing no carbonic acid gas; but in quantities much smaller than when carbonic acid gas was present.

In the dark, no oxygen gas is produced by plants, whatever be the elastic medium to which they are exposed; and no carbonic acid absorbed. In most cases, on the contrary, oxygen gas, if it be present, is absorbed, and carbonic acid gas is produced.

In the changes that take place in the composition of the organized parts it is probable that saccharine compounds are principally formed during the absence of light; gum, woody fibre, oils, and resins, during its presence; and the evolution of carbonic acid gas, or its formation during the night, may be necessary to give greater solubility to certain compounds in the plant. I once suspected that all the carbonic acid gas, produced by plants in the night, or in shade, might be owing to the decay of some part of the leaf, or epidermis; but the recent experiments of Mr. D. Ellis are opposed to this idea; and I found that a perfectly healthy plant of celery, placed in a given portion of air for a few hours only, occasioned a production of carbonic acid gas, and an absorption of oxygen.

* I found the Arenaria tenuifolia to produce oxygen in carbonic acid, which was nearly pure.

Some persons have supposed that plants exposed in the free atmosphere to the vicissitudes of sunshine and shade, light and darkness, consume more oxygen than they produce, and that their permanent agency upon air is similar to that of animals; and this opinion is espoused by the writer on the subject just quoted, in his ingenious researches on vegetation. But all experiments brought forwards in favour of this idea, and particularly his experiments, have been made under circumstances unfavourable to accuracy of result. The plants have been confined and supplied with food in an unnatural manner; and the influence of light upon them has been very much diminished by the nature of the media through which it passed. Plants confined in limited portions of atmospheric air soon become diseased; their leaves decay, and by their decomposition they rapidly destroy the oxygen of the air. In some of the early experiments of Dr. Priestley, before he was acquainted with the agency of light upon leaves, air that had supported combustion and respiration, was found purified by the growth of plants when they were exposed in it for successive days and nights; and his experiments are the more unexceptionable, as the plants, in many of them, grew in their natural states; and shoots, or branches from them, only were introduced through water into the confined atmosphere.

I have made some few researches on this subject, and I shall describe their results. On the 12th of July, 1800, I placed a turf four inches square, clothed with grass, principally meadow fox-tail, and white clover, in a porcelain dish, standing in a shallow tray filled with water; I then covered it with a jar of flint glass, containing 380 cubical inches of common air in its natural state. It was exposed in a garden, so as to be liable to

the same changes with respect to light as in the common air. On the 20th of July the results were examined. There was an increase of the volume of the gas, amounting to fifteen cubical inches; but the temperature had changed from 64° to 71°; and the pressure of the atmosphere, which on the 12th had been equal to the support of 30·1 inches of mercury, was now equal to that of 30·2. Some of the leaves of the white clover, and of the fox-tail were yellow, and the whole appearance of the grass less healthy than when it was first introduced. A cubical inch of the gas, agitated in lime-water, gave a slight turbidness to the water; and the absorption was not quite $\frac{1}{150}$ of its volume: 100 parts of the residual gas exposed to a solution of green sulphate of iron, impregnated with nitrous gas, a substance which rapidly absorbs oxygen from air, occasioned a diminution to 80 parts; 100 parts of the air of the garden occasioned a diminution to 79 parts.

If the results of this experiment be calculated upon, it will appear that the air had been slightly deteriorated by the action of the grasses. But the weather was unusually cloudy during the progress of the experiment; the plants had not been supplied in a natural manner with carbonic acid gas; and the quantity formed during the night, and, by the action of the faded leaves, must have been partly dissolved by the water; and that this was actually the case, I proved by pouring lime-water into the water, when an immediate precipitation was occasioned. This increase of azote I am inclined to attribute to common air disengaged from the water.

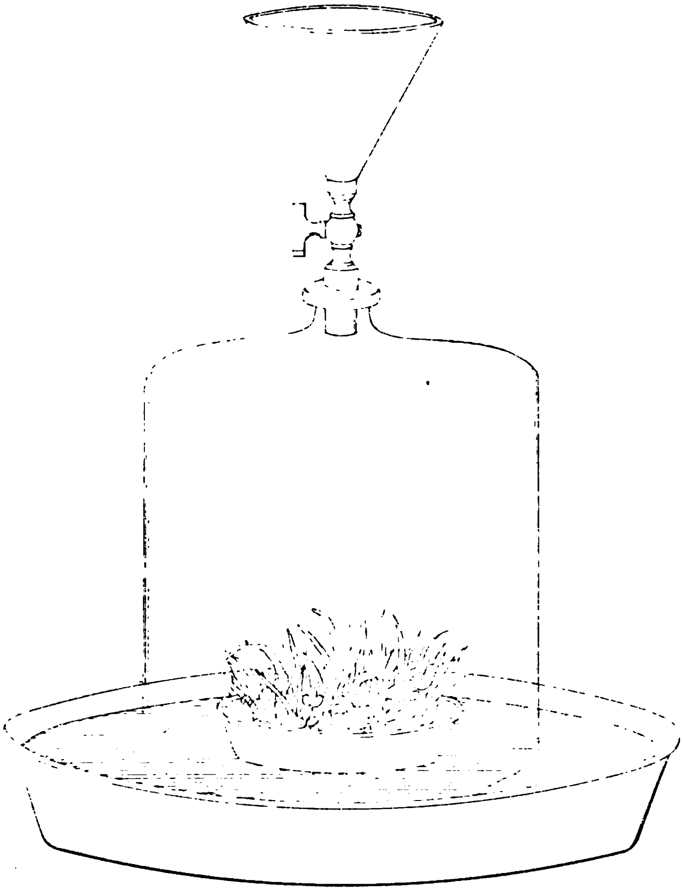
The following experiment I consider as conducted under circumstances more analagous to those existing in nature. A turf four inches square, from an irrigated meadow, clothed with common meadow grass, meadow

fox-tail grass, and vernal meadow grass, was placed in a porcelain dish, which swam on the surface of water impregnated with carbonic acid gas. A vessel of thin flint glass, of the capacity of 230 cubical inches, having a funnel furnished with a stop-cock inserted in the top, was made to cover the grass; and the apparatus was exposed in an open place; a small quantity of water was daily supplied to the grass by means of the stop-cock.* Every day, likewise, a certain quantity of water was removed by a siphon, and water saturated with carbonic acid gas was supplied in its place; so that it may be presumed that a small quantity of carbonic acid gas was constantly present in the receiver. On the 7th of July, 1807, the first day of the experiment, the weather was cloudy in the morning, but fine in the afternoon; the thermometer at 67, the barometer 30·2: towards the evening of this day a slight increase of the gas was perceived: the next three days were bright; but in the morning of the 11th the sky was clouded; a considerable increase of the volume of the gas was now observed: the 12th was cloudy, with gleams of sunshine; there was still an increase, but less than in the bright days: the 13th was bright. About nine o'clock A.M. on the 14th, the receiver was quite full; and considering the original quantity in the jar, it must have been increased by at least 30 cubical inches of elastic fluid: at times, during this day, globules of gas escaped. At ten on the morning of the 15th, I examined a portion of the gas: it contained less than $\frac{1}{20}$ of carbonic acid gas: 100 parts of it exposed to the impregnated solution left only 75 parts; so that the air was four per cent. purer than the air of the atmosphere.

I shall detail another similar experiment, made with

* See Fig. 17.

Fig 17



equally decisive results. A shoot from a vine, having three healthy leaves belonging to it, attached to its parent tree, was bent so as to be placed under the receiver which had been used in the last experiment; the water confining the common air was kept in the same manner impregnated with carbonic acid gas: the experiment was carried on from August 6th, till August 14th, 1807: during this time, though the weather had been generally clouded, and there had been some rain, the volume of elastic fluid continued to increase. Its quality was examined on the morning of the 15th; it contained $\frac{1}{42}$ of carbonic acid gas, and 100 parts of it afforded 23·5 of oxygen gas.

These facts confirm the popular opinion, that when the leaves of vegetables perform their healthy functions, they tend to purify the atmosphere in the common variations of weather, and changes from light to darkness.

In germination, and at the time of the decay of the leaf, oxygen must be absorbed; but when it is considered how large a part of the surface of the earth is clothed with perennial grasses, and that half of the globe is always exposed to the solar light, it appears by far the most probable opinion, that more oxygen is produced than consumed during the process of vegetation: and that it is this circumstance which is the principal cause of the uniformity of the constitution of the atmosphere.

Animals produce no oxygen gas during the exercise of any of their functions, and they are constantly consuming it; but the extent of the animal, compared to that of the vegetable kingdom, is very small; and the quantity of carbonic acid gas produced in respiration, and in various processes of combustion and fermentation, bears a proportion extremely minute to the whole volume of the atmosphere: if every plant, during the

progress of its life, makes a very small addition of oxygen to the air, and occasions a very small consumption of carbonic acid, the effect may be conceived adequate to the wants of nature.

It may occur as an objection to these views, that if the leaves of plants purify the atmosphere, towards the end of autumn, and through the winter, and early spring, the air in our climates must become impure, the oxygen in it diminish, and the carbonic acid gas increase, which is not the case; but there is a very satisfactory answer to this objection. The different parts of the atmosphere are constantly mixed together by winds, which, when they are strong, move at the rate of from 60 to 100 miles in an hour. In our winter, the south-west gales convey air which has been purified by the vast forests and savannahs of South America, and which, passing over the ocean, arrives in an uncontaminated state. The storms and tempests which often occur at the beginning, and towards the middle of our winter, and which generally blow from the same quarter of the globe, have a salutary influence. By constant agitation and motion, the equilibrium of the constituent parts of the atmosphere is preserved; it is fitted for the purposes of life; and those events which the superstitious formerly referred to the wrath of Heaven, or the agency of evil spirits, and in which they saw only disorder and confusion, are demonstrated, by science, to be ministrations of Divine intelligence, and connected with the order and harmony of our system.

I have reasoned, in a former part of this Lecture, against the close analogy which some persons have assumed between the absorption of oxygen and the formation of carbonic acid gas in germination, and in the respiration of the fœtus. Similar arguments will apply

against the pursuits of this analogy, between the functions of the leaves of the adult plant, and those of the lungs of the adult animal. Plants grow vigorously only when supplied with light; and most species die if deprived of it. It cannot be supposed that the production of oxygen from the leaf, which is known to be connected with its natural colour, is the exertion of a diseased function, or that it can acquire carbon in the day-time, when it is in most vigorous growth, when the sap is rising, when all its powers of obtaining nourishment are exerted, merely for the purpose of giving it off again in the night, when its leaves are closed, when the motion of the sap is imperfect, and when it is in a state approaching to that of quiescence. Many plants that grow upon rocks, or soils, containing no carbonic matter, can only be supposed to acquire their charcoal from the carbonic acid gas in the atmosphere; and the leaf may be considered at the same time as an organ of absorption, and an organ in which the sap may undergo different chemical changes.

When pure water only is absorbed by the roots of plants, the fluid, in passing into the leaves, will probably have greater power to absorb carbonic acid from the atmosphere. When the water is saturated with carbonic acid gas, some of this substance, even in the sunshine, may be given off by the leaves; but a part of it likewise will be always decomposed, which has been proved by the experiments of M. Sennebier.

When the fluid taken up by the roots of plants contains much carbonaceous matter, it is probable that plants may give off carbonic acid from their leaves even in the sunshine. In short, the function of the leaf must vary according to the composition of the sap passing through it, and according to the

nature of the products which are formed from it. When sugar is to be produced, as in early spring at the time of the development of buds and flowers, it is probable that less oxygen will be given off than at the time of the ripening of the seed, when starch, or gums, or oils, are formed; and the process of ripening the seed usually takes place when the agency of the solar light is most intense. When the acid juices of fruits become saccharine in the natural process of vegetation, more oxygen, there is every reason to believe, must be given off, or newly combined, than at other times; for, as it was shown in the Third Lecture, all the vegetable acids contain more oxygen than sugar. It appears probable, that in some cases in which oily and resinous bodies are formed in vegetation, water may be decomposed; its oxygen set free, and its hydrogen absorbed.

M. Berard, of Montpellier, has shown that fruits in ripening convert the oxygen of the air into carbonic acid; and that the process of ripening may be suspended by the exclusion of the fruit from oxygen gas, and that it will go on again after a certain interval of time. Unripe peaches, plums, and apricots, may be preserved in close bottles, filled with air deprived of oxygen, for from twenty days to a month; and pears and apples about three months, when they will afterwards ripen perfectly by exposure to air.

I have already mentioned, that some plants produce oxygen in pure water. Dr. Ingenhousz found this to be the case with species of the confervæ. I have tried the leaves of many plants, particularly those that produce volatile oils. When such leaves are exposed in water saturated with oxygen gas, oxygen is given off in the solar light; but the quantity is very small,

and always limited; nor have I been able to ascertain with certainty whether the vegetable powers of the leaf were concerned in the operation, though it seems probable. I obtained a considerable quantity of oxygen in an experiment made fifteen years ago, in which vine leaves were exposed to pure water; but on repeating the trial often since, the quantities have always been very much smaller. I am ignorant whether this difference is owing to the peculiar state of the leaves, or to some confervæ which might have adhered to the vessel, or to other sources of fallacy.

The most important and most common products of vegetables, mucilage, starch, sugar, and woody fibre, are composed of water, or the elements of water in their due proportion, and charcoal; and these, or some of them, exist in all plants: and the decomposition of carbonic acid, and the combination of water in vegetable structures, are processes which must occur almost universally.

When glutinous and albuminous substances exist in plants, the azote they contain may be suspected to be derived from the atmosphere; but no experiments have been made which prove this; they might easily be instituted upon mushrooms and funguses.

In cases in which buds are formed, or shoots thrown forth from roots, oxygen appears to be uniformly absorbed, as in the germination of seeds. I exposed a small potato, moistened with common water, to 24 cubical inches of atmospherical air, at a temperature of 59°. It began to throw forth a shoot on the third day; when it was half an inch long I examined the air; nearly a cubical inch of oxygen was absorbed, and about three-fourths of a cubical inch of carbonic acid formed. The juices in a shoot separated from the potato had a sweet taste; and the absorption of oxygen,

and the production of carbonic acid, were probably connected with the conversion of a portion of starch into sugar. When potatoes that have been frozen are thawed, they become sweet; probably oxygen is absorbed in this process; if so, the change may be prevented by thawing them out of the contact of air; under water, for instance, that has been recently boiled.

In the tillering of corn, that is, the production of new stalks round the original plume, there is every reason to believe that oxygen must be absorbed; for the stalk at which the tillering takes place always contains sugar, and the shoots arise from a part deprived of light. The drill husbandry favours this process; for loose earth is thrown by hoeing round the stalks: they are preserved from light, and yet supplied with oxygen. I have counted from 40 to 120 stalks produced from a grain of wheat, in a moderately good crop of drilled wheat. And we are informed by Sir Kenelm Digby, in 1660, that there was in the possession of the Fathers of the Christian Doctrine at Paris, a plant of barley, which they, at that time, kept by them as a curiosity, and which consisted of 249 stalks springing from one root, or grain; and in which they counted above 18,000 grains or seeds of barley.

The great increase which takes place in the transplantation of wheat depends upon the circumstance, that each layer thrown out in tillering may be removed, and treated as a distinct plant. In the Philosophical Transactions, vol. lviii. p. 203., the following statement may be found: Mr. C. Miller, of Cambridge, sowed some wheat on the 2d of June, 1766; and on the 8th of August, a plant was taken and separated into 18 parts, and replanted; these plants were again taken up,

and divided in the months of September and October, and planted separately to stand the winter, which division produced 67 plants. They were again taken up in March and April, and produced 500 plants: the number of ears thus formed from one grain of wheat was 21,109, which gave three pecks and three quarters of corn that weighed 47lbs. 7oz., and that were estimated at 576,840 grains.

It is evident from the statements just given, that the change which takes place in the juices of the leaf by the action of the solar light, must tend to increase the proportion of inflammable matter to their other constituent parts. And the leaves of the plants that grow in darkness or in shady places are uniformly pale; their juices are watery and saccharine, and they do not afford oils or resinous substances. I shall detail an experiment on this subject.

I took an equal weight, 400 grains, of the leaves of two plants of endive; one bright green, which had grown fully exposed to light, and the other almost white, which had been secluded from light by being covered with a box; after being both acted upon for some time by boiling water, in the state of pulp, the undissolved matter was dried, and exposed to the action of warm alcohol. The matter from the green leaves gave it a tinge of olive; that from the pale leaves did not alter its colour. Scarcely any solid matter was produced by evaporation of the alcohol that had been digested on the pale leaves: whereas by the evaporation of that from the green leaves a considerable residuum was obtained; five grains of which were separated from the vessel in which the evaporation was carried on; they burnt with flame, and appeared partly matter analogous to resin: 53 grains of woody fibre

were obtained from the green leaves, and only 31 from the pale leaves.

It has been mentioned in the Third Lecture, that the sap probably, in common cases, descends from the leaves into the bark; the bark is usually so loose in its texture, that the atmosphere may possibly act upon it in the cortical layers; but the changes taking place in the leaves appear sufficient to explain the difference between the products obtained from the bark and from the alburnum; the first of which contains more carbonaceous matter than the last.

When the similarity of the elements of different vegetable products is considered according to the views given in the Third Lecture, it is easy to conceive how the different organized parts may be formed from the same sap, according to the manner in which it is acted on by heat, light, and air. By the abstraction of oxygen, the different inflammable products, fixed and volatile oils, resins, camphor, woody fibre, &c. may be produced from saccharine or mucilaginous fluids; and by the abstraction of carbon and hydrogen, starch, sugar, the different vegetable acids and substances soluble in water, may be formed with highly combustible and insoluble substances. Even the limpid volatile oils which convey the fragrance of the flower, consist of different proportions of the same essential elements as the dense woody fibre; and both are formed by different changes in the same organs, from the same materials, and at the same time.

M. Vauquelin has lately attempted to estimate the chemical changes taking place in vegetation, by analyzing some of the organized parts of the horse-chesnut in their different stages of growth. He found in the buds collected, March 7, 1812, tanning principle, and

albuminous matter capable of being obtained separately, but, when obtained, combining with each other. In the scales surrounding the buds, he found the tanning principle, a little saccharine matter, resin, and a fixed oil. In the leaves fully developed, he discovered the same principles as in the buds; and in addition, a peculiar green resinous matter. The petals of the flower yielded a yellowish resin, saccharine matter, albuminous matter, and a little wax: the stamina afforded sugar, resin, and tannin.

The young chesnuts examined immediately after their formation, afforded a large quantity of a matter which appeared to be a combination of albuminous matter and tannin. All the parts of the plant afforded saline combinations of the acetic and phosphoric acids.

M. Vauquelin could not obtain a sufficient quantity of the sap of the horse-chesnut for examination, a circumstance much to be regretted; and he has not stated the relative quantities of the different substances in the buds, leaves, flowers, and seeds. It is probable, however, from his unfinished details, that the quantity of resinous matter is increased in the leaf, and that the white fibrous pulp of the chesnut is formed by the mutual action of albuminous and astringent matter, which probably are supplied by different cells or vessels. I have already mentioned * that the cambium, from which the new parts in the trunk and branches appear to be formed, probably owes its power of consolidation to the mixture of two different kinds of sap; one of which flows upwards from the roots, and the other of which probably descends from the leaves. I attempted, in May, 1804, at the time the cambium was forming in the oak, to ascertain the nature of the action of the sap of the albur-

* Page 296.

num upon the juices of the bark. By perforating the alburnum in a young oak, and applying an exhausting syringe to the aperture, I easily drew out a small quantity of sap. I could not, however, in the same way obtain sap from the bark. I was obliged to recur to the solution of its principles in water, by infusing a small quantity of fresh bark in warm water; the liquid obtained in this way, was highly coloured and astringent; and produced an immediate precipitate in the alburnous sap, the taste of which was sweetish, and slightly astringent, and which was colourless.

The increase of trees and plants, must depend upon the quantity of sap which passes into their organs; upon the quality of this sap; and on its modification, by the principles of the atmosphere. Water, as it is the vehicle of the nourishment of the plant, is the substance principally given off by the leaves. Dr. Hales found that a sunflower, in one day of twelve hours, transpired by its leaves one pound fourteen ounces of water, all of which must have been imbibed by its roots.

The powers which cause the ascent of the sap, have been slightly touched upon in the Second and Third Lectures. The roots imbibe fluids from the soil, by capillary attraction; but this power alone is insufficient to account for the rapid elevation of the sap into the leaves. This is fully proved by the following fact, detailed by Dr. Hales, vol. i. of the Vegetable Statics, page 114.:—A vine branch of four or five years old was cut through, and a glass tube carefully attached to it; this tube was bent as a siphon, and filled with quicksilver; so that the force of the ascending sap could be measured by its effect in elevating the quicksilver. In a few days it was found that the sap had been propelled forwards with so much force, as to raise the quicksilver

to 38 inches, which is a force considerably superior to that of the usual pressure of the atmosphere. Capillary attraction can only be exerted by the surfaces of small vessels, and can never raise a fluid into tubes above the vessels themselves.

I referred in the beginning of the Third Lecture, to Mr. Knight's opinion, that the contractions and expansions of the silver grain in the alburnum, are the most efficient cause of the ascent of the fluids contained in its pores and vessels. The views of this excellent physiologist, are rendered extremely probable, by the facts he has brought forward in support of them. Mr. Knight found that a very small increase of temperature was sufficient to cause the fibres of the silver grain to separate from each other, and that a very slight diminution of heat produced their contraction. The sap rises most vigorously in spring and autumn, at the time the temperature is variable; and if it be supposed that, in expanding and contracting, the elastic fibres of the silver grain exercise a pressure upon the cells and tubes containing the fluid absorbed by the capillary attraction of the roots, this fluid must constantly move upwards towards the points where a supply is needed.

The experiments of Montgolfier, the celebrated inventor of the balloon, have shown that water may be raised almost to an indefinite height by a very small force, provided its pressure be taken off by continued divisions in the column of fluid. This principle, there is great reason to suppose, must operate in assisting the ascent of the sap in the cells and vessels of plants which have no rectilineal communication, and which everywhere oppose obstacles to the perpendicular pressure of the sap.

The changes taking place in the leaves and buds, and

the degree of their power of transpiration, must be intimately connected likewise with the motion of the sap upwards. This is shown by several experiments of Dr. Hales.

A branch from an apple-tree was separated and introduced into water, and connected with a mercurial gauge. When the leaves were upon it, it raised the mercury, by the force of the ascending juices, to four inches; but a similar branch, from which the leaves were removed, scarcely raised it a quarter of an inch.

Those trees, likewise, whose leaves are soft, and of a spongy texture, and porous at their upper surfaces, displayed by far the greatest powers with regard to the elevation of the sap.

The same accurate philosopher, whom I have just quoted, found that the pear, quince, cherry, walnut, peach, gooseberry, water-elder, and sycamore, which have all soft and unvarnished leaves, raised the mercury under favourable circumstances from three to six inches. Whereas the elm, oak, chesnut, hazel, sallow, and ash, which have firmer and more glossy leaves, raised the mercury only from one to two inches. And the evergreens, and trees bearing varnished leaves, scarcely at all affected it; particularly the laurel and the laurustinus.

It will be proper to mention the facts which show that, in many cases, fluids descend through the bark. Mr. Knight has shown, in the Philosophical Transactions, that long strips of bark, everywhere detached from the alburnum of the tree, except at their upper ends, deposited as much alburnum as they could have done, if they had retained their natural position. In these cases, the sap must have descended through the bark wholly.

M. Baisse placed branches of different trees in an infusion of madder, and kept them there for a long time. He found, in all cases, that the wood became red before the bark; and that the bark began to receive no tinge till the whole of the wood was coloured, and till the leaves were affected; and that the colouring matter first appeared above, in the bark immediately in contact with the leaves.

Similar experiments were made by M. Bonnet, and with analogous results, though not so perfectly distinct as those of M. Baisse.

Du Hamel found that, in different species of the pine and other trees, when strips of bark were removed, the upper part of the wound only emitted fluid, whilst the lower part remained dry.

This may likewise be observed in the summer in fruit trees, when the bark is wounded, the alburnum remaining untouched.

The motion of the sap through the bark, seems principally to depend upon gravitation. When the watery particles have been considerably dissipated by the transpiring functions of the leaves, and the mucilaginous, inflammable, and astringent constituents, increased by the agency of heat, light, and air, the continued impulse upwards from the alburnum, forces the remaining inspissated fluid into the cortical vessels, which receive no other supply. In these, from its weight, its natural tendency must be to descend: and the rapidity of the descent, must depend upon the general consumption of the fluids of the bark in the living processes of vegetation; for there is every reason to believe that no fluid passes into the soil through the roots; and it is impossible to conceive a free lateral communication between the absorbent vessels of the alburnum in the roots, and

the transporting or carrying vessels of the bark; for if such a communication existed, there is no reason why the sap should not rise through the bark, as well as through the alburnum; for the same physical powers would then operate upon both.

Some authors have supposed that the sap rises in the alburnum, and descends through the bark, in consequence of a power similar to that which produces the circulation of the blood in animals; a force analogous to the muscular force in the sides of the vessels.

This analogy has, however, in general, been too much insisted upon, and too loosely stated; there are undoubtedly resemblances more or less remote in every part of created nature; but the irritability of the muscular fibre in animals, and the contractibility of the vascular system in plants, appear to depend upon entirely different causes.

In crystallization, or the regular arrangement of inorganic substances, there is a constant increase of mattter from the attraction and juxtaposition of like parts or molecules. In vegetation a germ expands by the assimilation of a variety of new aliments, and by powers entirely different from those of common inorganic matter; but there seems to be no system of nerves, as in animals, which is essential to irritability. We know so little of the refined powers and properties of matter, that we can give little more than vague hypotheses as to the cause of the movement of the fluids in the vegetable cells or tubes; yet it is impossible not to allow common material agents a much greater share in producing this phenomenon, than they exercise in animal life.

Whoever will peruse any considerable part of the Vegetable Statics of Hales, must receive a deep im-

pression of the dependence of the motion of the sap upon physical causes. In the same tree, this sagacious person observed that in a cold cloudy morning, when no sap ascended, a sudden change was produced by a gleam of sunshine of half an hour, and a vigorous motion of the fluid. The alteration of the wind from south to the north immediately checked the effect. On the coming on of a cold afternoon after a hot day, the sap that had been rising began to fall. A warm shower and a sleet storm produced opposite effects.

Many of his observations likewise show that the different powers which act in the adult tree, produce different effects at different seasons.

Thus in the early spring, before the buds expand, the variations of the temperature, and changes of the state of the atmosphere with regard to moisture and dryness, exert their great effects upon the expansions and contractions of the vessels; and then the tree is in what is called by gardeners its bleeding season.

When the leaves are fully expanded, the great determination of the sap is to these new organs. And hence a tree which emits sap copiously from a wound whilst the buds are opening, will no longer emit it in summer when the leaves are perfect; but in the variable weather, towards the end of autumn, when the leaves are falling, it will again possess the power of bleeding in a very slight degree in the warmest days; but at no other times.

In all these circumstances there is nothing truly analogous to the irritable action of animal systems.

In animal systems the heart and arteries are in constant pulsation. Their functions are unceasingly performed in all climates, and in all seasons; in winter, as well as in spring; upon the arctic snows, and under the

tropical suns. They neither cease in the periodical nocturnal sleep, common to most animals; nor in the long sleep of winter, peculiar to a few species. The power is connected with animation, is limited to beings possessing the means of voluntary locomotion; it co-exists with the first appearance of vitality; it disappears only with the last spark of life.

As the operation of the different physical agents upon the sap vessels of plants ceases, and the fluid becomes quiescent, the materials dissolved in it by heat are deposited in the cells of the alburnum; and in consequence of this deposition, a nutritive matter is provided for the first wants of the plant in early spring, to assist the opening of the buds, and their expansion, when the motion from the want of leaves is as yet feeble.

This beautiful principle in the vegetable economy was first pointed out by Dr. Darwin; and Mr. Knight has given a number of experimental elucidations of it.

Mr. Knight made numerous incisions into the alburnum of the sycamore and the birch, at different heights; and in examining the sap that flowed from them, he found it more sweet and mucilaginous in proportion as the aperture from which it flowed was elevated; which he could ascribe to no other cause than to its having dissolved sugar and mucilage, which had been stored up through the winter.

He examined the alburnum in different poles of oak in the same forest; of which some had been felled in winter, and others in summer; and he always found most soluble matter in the wood felled in winter, and its specific gravity was likewise greater.

In all perennial trees this circumstance takes place; and likewise in grasses and shrubs. The joints of the perennial grasses contain more saccharine and mucila-

ginous matter in winter than at any other season; and this is the reason why the fiorin or Agrostis alba, which abounds in these joints, affords so useful a winter food.

The roots of shrubs contain the largest quantity of nourishing matter in the depth of winter; and the bulb in all plants possessing it is the receptacle in which nourishment is hoarded up during winter.

In annual plants the sap seems to be fully exhausted of all its nutritive matter by the production of flowers and seeds; but if parts of annual plants, having leaves and buds, be detached and kept, so that they do not expend themselves by affording blossoms or seeds, the same individual life may be preserved through many years. It appears, therefore, as Mr. Knight observes, to be habit only, not life, that is annual in such plants.

When perennial grasses are cropped very close by feeding cattle late in autumn, it has been often observed by farmers that they never rise vigorously in the spring; and this is owing to the removal of that part of the stalk which would have afforded them concrete sap, their first nourishment.

Ship builders prefer for their purposes that kind of oak-timber afforded by trees that have had their bark stripped off in spring, and which have been cut in the autumn or winter following. The reason of the superiority of this timber is, that the concrete sap is expended in the spring in the sprouting of the leaf; and the circulation being destroyed, it is not formed anew; and the wood having its pores free from saccharine matter, is less liable to undergo fermentation from the action of moisture and air.

In perennial trees a new alburnum, and consequently a new system of vessels, is annually produced, and the

nutriment for the next year deposited in them; so that the new buds, like the plume of the seed, are supplied with a reservoir of matter essential to their first development.

The old alburnum gradually loses its vascular structure, and, being constantly pressed upon by the expansive force of the new fibres, becomes harder, denser, and at length becomes heart-wood; and in a certain time obeys the common laws of dead matter, decays, decomposes, and is converted into aëriform and carbonic elements; into those principles from which it was originally formed.

The decay of the heart-wood seems to constitute the great limit to the age and size of trees. And in young branches from old trees, it is much more liable to decompose than in similar branches from seedlings. This is likewise the case with grafts. The graft is only nourished by the sap of the tree to which it is transferred; its properties are not changed by it: the leaves, blossoms, and fruits are of the same kind as if it had vegetated upon its parent stock. The only advantage to be gained in this way, is the affording to a graft from an old tree a more plentiful and healthy food than it could have procured in its natural state; it is rendered for a time more vigorous, and produces fairer blossoms and richer fruits. But it partakes not merely of the obvious properties, but likewise of the infirmities and disposition to old age and decay, of the tree whence it sprung.

This seems to be distinctly shown by the observations and experiments of Mr. Knight. He has, in a number of instances, transferred the young scions and healthy shoots from old esteemed fruit-bearing trees to young seedlings. They flourished for two or three years; but they soon became diseased and sickly, like their parent trees.

It is from this cause that so many of the apples formerly celebrated for their taste and their uses in the manufacture of cyder are gradually deteriorating, and many will soon disappear. The red streak, and the moil, so excellent in the beginning of the last century, are now in the extremest stage of their decay; and however carefully they are ingrafted, they merely tend to multiply a sickly and exhausted variety.*

The trees possessing the firmest and the least porous heart-wood are the longest in duration.

In general, the quantity of charcoal afforded by woods offers a tolerably accurate indication of their durability: those most abundant in charcoal and earthy matter are most permanent; and those that contain the largest proportion of gaseous elements are the most destructible.

Amongst our own trees, the chesnut and the oak are pre-eminent as to durability; and the chesnut affords rather more carbonaceous matter than the oak.

In old Gothic buildings these woods have been sometimes mistaken one for the other; but they may be easily known by this circumstance, that the pores in the alburnum of the oak are much larger and more thickly set, and are easily distinguished; whilst the pores in the chesnut require glasses to be seen distinctly.

In consequence of the slow decay of the heart-wood of the oak and chesnut, these trees, under favourable circumstances, attain an age which cannot be much short of 1000 years.

The beech, the ash, and the sycamore, most likely never live half as long. The duration of the apple-tree is not, probably, much more than 200 years; but the

* [The accuracy of this doctrine has been questioned; vide M. de Candolle's Physiologie Végétale, liv. 4. chap. xi.]

pear-tree, according to Mr. Knight, lives through double this period. Most of our best apples are supposed to have been introduced into Britain by a fruiterer of Henry the Eighth, and they are now in a state of old age.

The oak and chesnut decay much sooner in a moist situation than in a dry and sandy soil; and their timber is less firm. The sap vessels in such cases are more expanded, though less nourishing matter is carried into them; and the general texture of the formations of wood necessarily less firm. Such wood splits more easily, and is more liable to be affected by variations in the state of the atmosphere.

The same trees, in general, are much longer-lived in the northern than in the southern climates. The reason seems to be, that all fermentation and decomposition are checked by cold; and at very low temperatures both animal and vegetable matters altogether resist putrefaction: and in the northern winter, not only vegetable life, but likewise vegetable decay, must be at a stand.

The antiputrescent quality of cold climates is fully illustrated in the instances of the rhinoceros and mammoth, lately found in Siberia, entire beneath the frozen soil, in which they must probably have existed from the time of the deluge. I examined a part of the skin of the mammoth sent to this country, on which there was some coarse hair; it had all the chemical characters of recently dried skin.

Trees that grow in situations much exposed to winds, have harder and firmer wood than such as are considerably sheltered. The dense sap is determined by the agitation of the smaller branches to the trunk and larger branches, where the new alburnum formed is conse-

quently thick and firm. Such trees abound in the crooked limbs fitted for forming knee-timber, which is necessary for joining the decks and the sides of ships. The gales in elevated situations gradually act so as to give the tree the form best calculated to resist their effects. And the mountain oak rises robust and sturdy; fixed firmly in the soil, and able to oppose the full force of the tempest.

The decay of the best varieties of fruit-bearing trees which have been distributed through the country by grafts is a circumstance of great importance. There is no mode of preserving them; and no resource, except that of raising new varieties by seeds.

Where a species has been ameliorated by culture, the seeds it affords, other circumstances being similar, produce more vigorous and perfect plants; and in this way the great improvements in the production of our fields and gardens seem to have been occasioned.

Wheat, in its indigenous state, as a natural production of the soil, appears to have been a very small grass; and the case is still more remarkable with the apple and the plum. The crab seems to have been the parent of all our apples. And two fruits can scarcely be conceived more different, in colour, size, and appearance, than the wild plum and the rich magnum bonum.

The seeds of plants exalted by cultivation always furnish large and improved varieties; but the flavour, and even the colour of the fruit, seems to be a matter of accident. Thus a hundred seeds of the golden pippin will all produce fine large-leaved apple-trees, bearing fruit of a considerable size; but the tastes and colours of the apples from each will be different, and none will be the same in kind as those of the pippin itself. Some will be sweet, some sour, some bitter, some mawkish,

some aromatic; some yellow, some green, some red, and some streaked. All the apples will, however, be much more perfect than those from the seeds of a crab, which produce trees all of the same kind, and all bearing sour and diminutive fruit.

The power of the horticulturist extends only to the multiplying excellent varieties by grafting. They cannot be rendered permanent; and the good fruits at present in our gardens are the produce of a few seedlings, selected probably from hundreds of thousands; the results of great labour and industry, and multiplied experiments.

The larger and thicker the leaves of a seedling, and the more expanded its blossoms, the more it is likely to produce a good variety of fruit. Short-leaved trees should never be selected; for these approach nearer to the original standard: whereas the other qualities indicate the influence of cultivation.

In the general selection of seeds, it would appear that those arising from the most highly cultivated varieties of plants are such as give the most vigorous produce; but it is necessary from time to time to change, and, as it were, to cross the breed.

By applying the pollen, or dust of the stamina, from one variety to the pistil of another of the same species, a new variety may be easily produced; and Mr. Knight's experiments seem to warrant the idea that great advantages may be derived from this method of propagation.

Mr. Knight's large peas, produced by crossing two varieties, are celebrated amongst horticulturists, and will, I hope, soon be cultivated by farmers.

I have seen several of his crossed apples, which promise to rival the best of those which are gradually dying away in the cider countries.

And his experiments on the crossing of wheat, which is very easily effected, merely by sowing the different kinds together, lead to a result which is of considerable importance. He says, in the Philosophical Transactions for 1799, "In the years 1795 and 1796, when almost the whole crop of corn in the island was blighted, the varieties obtained by crossing *alone* escaped, though sown in several soils, and in very different situations."

The processes of gardening for increasing the number of fruit-bearing branches, and for improving the fruit upon particular branches, will all admit of elucidation from the principles that have been advanced in this lecture.

By making trees espaliers, the force of gravity is particularly directed towards the lateral parts of the branches, and more sap determined towards the fruit buds; and hence they are more likely to bear when in a horizontal than when in a vertical position.

The twisting of a wire, or tying a thread round a branch, has been often recommended as a means of making it produce fruit. In this case the descent of the sap in the bark must be impeded above the ligature; and more nutritive matter consequently retained and applied to the expanding parts.

In engrafting, the vessels of the bark of the stock and the graft cannot so perfectly come in contact as the alburnous vessels, which are much more numerous, and equably distributed; hence the circulation downwards is probably impeded, and the tendency of the graft to evolve its fruit-bearing buds increased.

In transplanting trees, if their size is at all considerable, they should be stripped of a portion of their branches and leaves by cutting; for they must in the

process of removal from the soil lose a great part of their roots and fine radical fibres; and supposing all their leaves remaining, they would die from exhaustion of their moisture by the great evaporating surface.

By lopping trees more nourishment is supplied to the remaining parts; for the sap flows laterally as well as perpendicularly. The same reasons will apply to explain the increase of the size of fruits by diminishing the number upon a tree.

As plants are capable of amelioration by peculiar methods of cultivation, and of having the natural term of their duration extended; so, in conformity to the general law of change, they are rendered unhealthy by being exposed to peculiarly unfavourable circumstances, and liable to premature old age and decay.

The plants of warm climates transplanted into cold ones, or of cold ones transplanted into warm ones, if not absolutely destroyed by the change of situation, are uniformly rendered unhealthy.

Few of the tropical plants, as is well known, can be raised in this country, except in hot-houses. The vine during the whole of our summer may be said to be in a feeble state with regard to health; and its fruit, except in very extraordinary cases, always contains a superabundance of acid. The gigantic pine of the north, when transported into the equatorial climates, becomes a degenerated dwarf; and a great number of instances of the same kind might be brought forward.

Much has been written, and many very ingenious remarks have been made by different philosophers, upon what have been called the habits of plants. Thus, in transplanting a tree, it dies or becomes unhealthy, unless its position with respect to the sun is the same as before. The seeds brought from warm climates germi-

nate here much more early in the season than the same species brought from cold climates. The apple-tree from Siberia, where the short summer of three months immediately succeeds the long winter, in England usually puts forth its blossoms in the first year of its transplantation, on the appearance of mild weather; and is often destroyed by the late frosts of the spring.

It is not difficult to explain this principle so intimately connected with the healthy or diseased state of plants. The organization of the germ, whether in seeds or buds, must be different, according as more or less heat or alternations of heat and cold have affected it during its formation; and the nature of its expansion must depend wholly on this organization. In a changeable climate the formations will have been interrupted, and in different successive layers. In an equal temperature they will have been uniform; and the operation of new and sudden causes will of course be severely felt.

The disposition of trees may, however, be changed gradually in many instances; and the operation of a new climate in this way be made supportable. The myrtle, a native of the south of Europe, inevitably dies if exposed in the early stage of its growth to the frosts of our winter; but if kept in a green-house during the cold season for successive years, and gradually exposed to low temperatures, it will, in an advanced stage of growth, resist even a very severe cold. And in the south and west of England the myrtle flourishes, produces blossoms and seeds, in consequence of this process, as an unprotected standard tree; and the layers from such trees are much more hardy than the layers from myrtles reared within doors.

The arbutus, probably originally from similar cultivation, has become the principal ornament of the lakes of the south of Ireland. It thrives even in bleak mountain situations; and there can be little doubt but that the offspring of this tree, inured to a temperate climate, might be easily spread in Britain.

The same principles that apply to the effects of heat and cold will likewise apply to the influence of moisture and dryness. The layers of a tree habituated to a moist soil will die in a dry one; even though such a soil is more favourable to the general growth of the species. And, as was stated, p. 331, trees that have been raised in the centre of woods are sooner or later destroyed, if exposed in their adult state to blasts, in consequence of the felling of the surrounding timber.

Trees, in all cases in which they are exposed in high and open situations to the sun, the winds and the rain, as I just now noticed, become low and robust, exhibiting curved limbs, but never straight and graceful trunks. Shrubs and trees, on the contrary, which are too much secluded from the sun and wind, extend exceedingly in height, but present at the same time slender and feeble branches; their leaves are pale and sickly, and in extreme cases they do not bear fruit. The exclusion of light alone is sufficient to produce this species of disease, as would appear from the experiments of Bonnet. This ingenious physiologist sowed three seeds of the pea in the same kind of soil: one he suffered to remain exposed to the free air; the other he enclosed in a tube of glass; and the third in a tube of wood. The pea in the tube of glass sprouted, and grew in a manner scarcely at all different from that under usual circumstances; but the plant in the tube of wood, deprived of

light, became white and slender, and grew to a much greater height.

The plants growing in a soil incapable of supplying them with sufficient manure, or dead organized matter, are very generally low, having brown or dark green leaves, and their woody fibre abounds in earth. Those vegetating in peaty soils, or in lands too copiously supplied with animal or vegetable matter, rapidly expand, produce large bright green leaves, abound in sap, and generally blossom prematurely.

Where a land is too rich for corn, it is not an uncommon practice to cut down the first stalks, as by these means its exuberance is corrected, and it is less likely to fall before the grain is ripe: excess of poverty, or of richness, is almost equally fatal to the hopes of the farmer; and the true constitution of the soil for the best crop is that in which the earthy materials, the moisture and manure, are properly associated; and in which the decomposable vegetable or animal matter does not exceed one-fourth of the weight of the earthy constituents.

The canker, or erosion of the bark and wood, is a disease produced often in trees by a poverty of soil; and it is invariably connected with old age. The cause seems to be an excess of alkaline and earthy matter in the descending sap. I have often found carbonate of lime on the edges of the canker in apple trees; and ulmin, which contains fixed alkali, is abundant in the canker of the elm. The old age of a tree, in this respect, is faintly analogous to the old age of animals, in which the secretions of solid bony matter are always in excess, and the tendency to ossification great.

The common modes of attempting to cure the canker are by cutting the edges of the bark, binding new bark

upon it, or laying on a plaster of earth: but these methods, though they have been much extolled, probably do very little in producing a regeneration of the part. Perhaps the application of a weak acid to the canker might be of use; or, where the tree is of great value, it may be watered occasionally with a very diluted acid. The alkaline and earthy nature of the morbid secretion warrants the trial; but circumstances that cannot be foreseen may occur, to interfere with the success of the experiment.

Besides the diseases having their source in the constitution of the plant, or in the unfavourable operation of external elements, there are many others perhaps more injurious, depending upon the operations and powers of other living beings; and such are the most difficult to cure, and the most destructive to the labours of the husbandman.

Parasitical plants of different species, which attach themselves to trees and shrubs, feed on their juices, destroy their health, and finally their life, abound in all climates; and are, perhaps, the most formidable of the enemies of the superior and cultivated vegetable species.

The mildew, which has often occasioned great havoc in our wheat crops, and which was particularly destructive in 1804, is a species of fungus, so small as to require glasses to render its form distinct, and rapidly propagated by its seeds.

This has been shown by various botanists; and the subject has received a full illustration from the researches of the late ever-to-be-lamented Sir Joseph Banks.

The fungus rapidly spreads from stalk to stalk, fixes itself in the cells connected with the common tubes,

and carries away and consumes that nourishment which should have been appropriated to the grain.

Various remedies have been proposed for this disease. The Rev. Dr. Cartwright states that he has successfully treated it, by the application of a solution of salt, by a common gardening pot, to the stalks of the corn. This is a subject worthy of the most minute investigation; and all methods should be tried which promise to eradicate so great an evil. As the fungus increases by the diffusion of its seeds, great care should be taken that no mildewed straw is carried in the manure used for corn; and in the early crop, if mildew is observed upon any of the stalks of corn, they should be carefully removed, and treated as weeds.

The popular notion amongst farmers, that a barberry-tree in the neighbourhood of a field of wheat often produces the mildew, deserves examination. This tree is frequently covered with a fungus, which, if it should be shown to be capable of degenerating into the wheat fungus, would offer an easy explanation of the effect.

There is some reason to believe, from the researches of Sir Joseph Banks, that the smut in wheat likewise is produced by a very small fungus which fixes on the grain: the products that it affords by analysis are similar to those afforded by the puff-ball; and it is difficult to conceive, that without the agency of some organized structure, so complete a change should be affected in the constitution of the grain.

The mistletoe and the ivy, the moss and the lichen, in fixing upon trees, uniformly injure their vegetative processes, though in very different degrees. They are supported from the lateral sap-vessels, and de-

prive the branches above of a part of their nourishment.

The insect tribes are scarcely less injurious than the parasitical plants.

To enumerate all the animal destroyers and tyrants of the vegetable kingdom, would be to give a catalogue of the greater number of the classes in zoology. Every species of plant almost is the peculiar resting-place or dominion of some insect tribe; and from the locust, the caterpillar, and snail, to the minute aphis, a wonderful variety of the inferior insects are nourished, and live by their ravages upon the vegetable world.

I have already referred to the insect which feeds on the seed-leaf of the turnip.

The Hessian fly, still more destructive to wheat, has in some seasons threatened the United States with a famine. And the French government in 1813 issued decrees with a view to occasion the destruction of the larvæ of the grasshopper.

In general, wet weather is most favourable to the propagation of mildew, funguses, rust, and the small parasitical vegetables; dry weather, to the increase of the insect tribes. Nature, amidst all her changes, is continually directing her resources towards the production and multiplication of life; and in the wise and grand economy of the whole system, even the agents that appear injurious to the hopes, and destructive to the comforts, of man, are, in fact, ultimately connected with a more exalted state of his powers and his condition. His industry is awakened, his activity kept alive, even by the defects of climates and season. By the accidents which interfere with his efforts, he is made to exert his talents, to look farther into futurity, and to

consider the vegetable kingdom not as a secure and unalterable inheritance, spontaneously providing for his wants; but as a doubtful and insecure possession, to be preserved only by labour, and extended and perfected by ingenuity.

END OF VOL. VII.

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